Television

Prof. Mohamed Nasr

- <u>Any display system that</u>
  - Has digital processing of **one or more** of its inputs
  - Includes the function of showing video

- <u>Divide into 4 segments</u>
  - **Monitor**/TV
    - Digital monitor with video function – 15” XGA LCD Monitor/TV
  - **TV**/Monitor
    - HD-Ready TV / EDTV / SDTV / 100 Hz TV – digital displays often include monitor as additional function
  - **MPEG TV**
    - Integrated HDTV (USA); iDTV [Integrated Digital TV] (Europe); BS Digital (Japan)
  - **Smart (IP) TV**
    - Internet connectivity, built-in hard-drive (PVR), interactivity etc

High Definition and Digital TV

- Digital and HD Available Today!
- Soon (one year from now) Analog Broadcasts Cease
- What Does This Mean To Us?
  - Why Do You Care?
  - What Do I Need?
  - What Will Happen to My Captions?

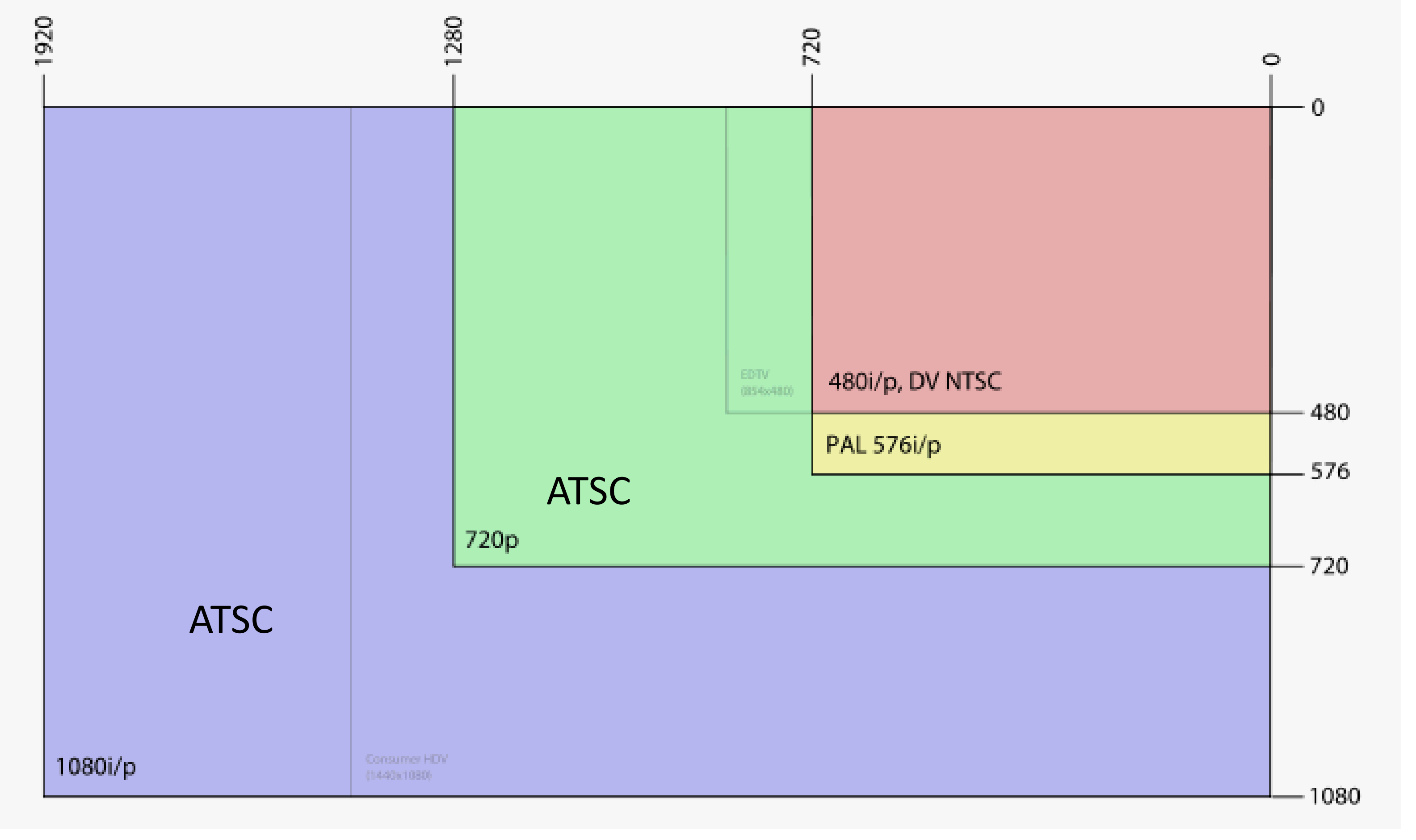
What’s Changing

- Originally TVs Only Received “Over the Air” Analog
- Then came Cable
- And Satellite
- Then came VCRs
- And DVDs
- And TiVos and DVRs
- And the Internet
- And Computers
- And Digital and Video Cameras
- And High Definition and Digital TV
- Then (Feb 17, 2009) Analog Broadcasts Cease

Why is it Changing?

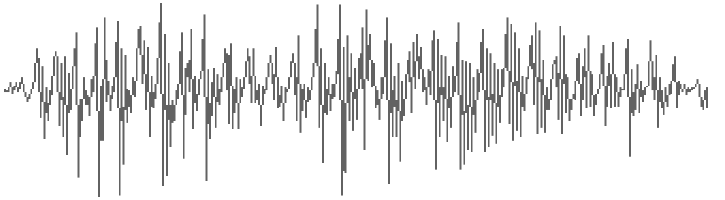
- No snow, no static, no ghosts
- Higher resolution images, and Sound
- Additional channels
- Frees up Bandwidth for Other Important Needs
- More Options
  - Improved captions (but not without pain)
  - Interactive TV
  - TV to your Cell Phone or PDA? (maybe later)

Let’s Talk Resolution



Analog vs. Digital

- Analog
  - An analog signal is one that continuously varies and the strength of the signal carries the information.



- Digital
  - A digital signal is one that contains coded information that carries the information.

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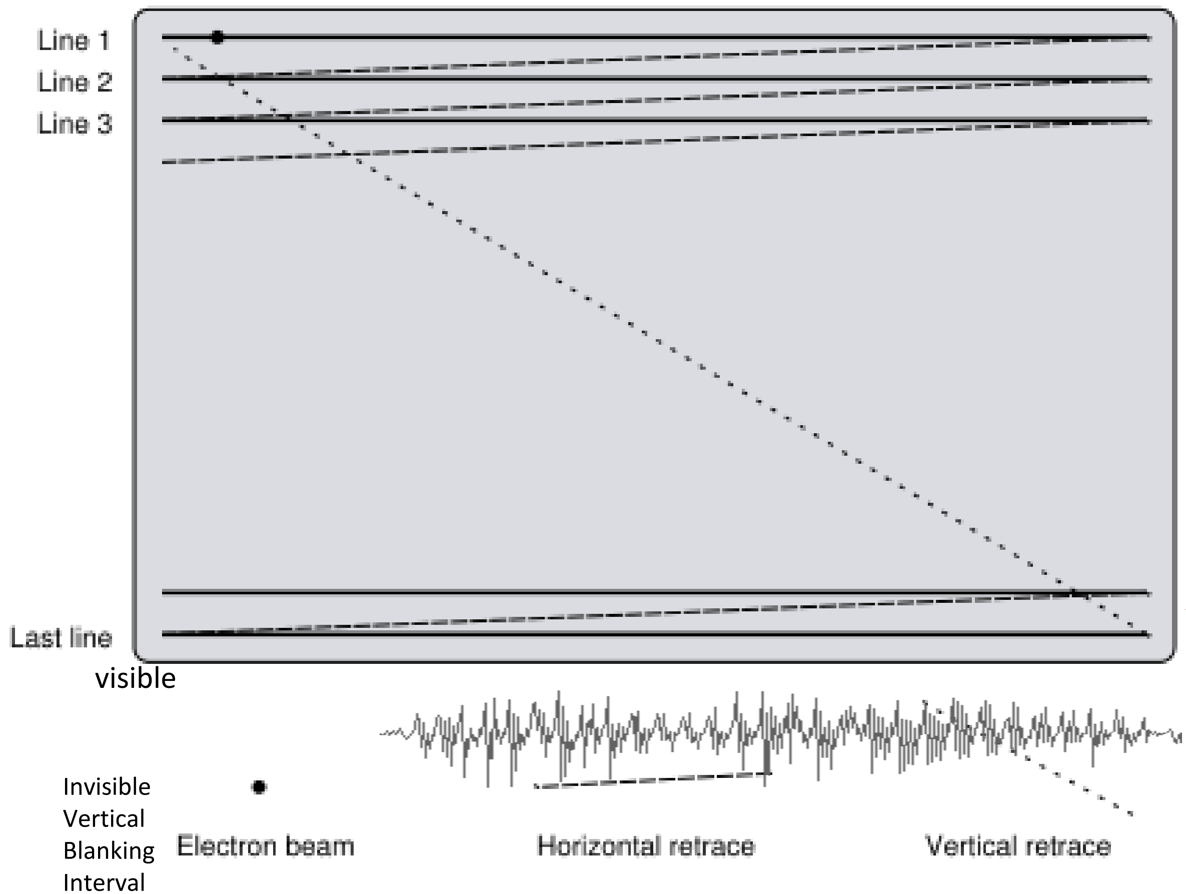
Analog vs. Digital

- Analog
  - Records
  - Film (movies, and photos)
  - Most VCRs
  - Most TVs (except the new ones)
  - Waves (sound, radio, light, water… nobody’s sure about light)
  - All hearing aids, until about 10 years ago
- Digital
  - DVDs
  - CDs
  - Digital Photos
  - Computers
  - The Internet
  - New TVs
  - Satellite Radios
  - All CIs and Almost all Hearing Aids

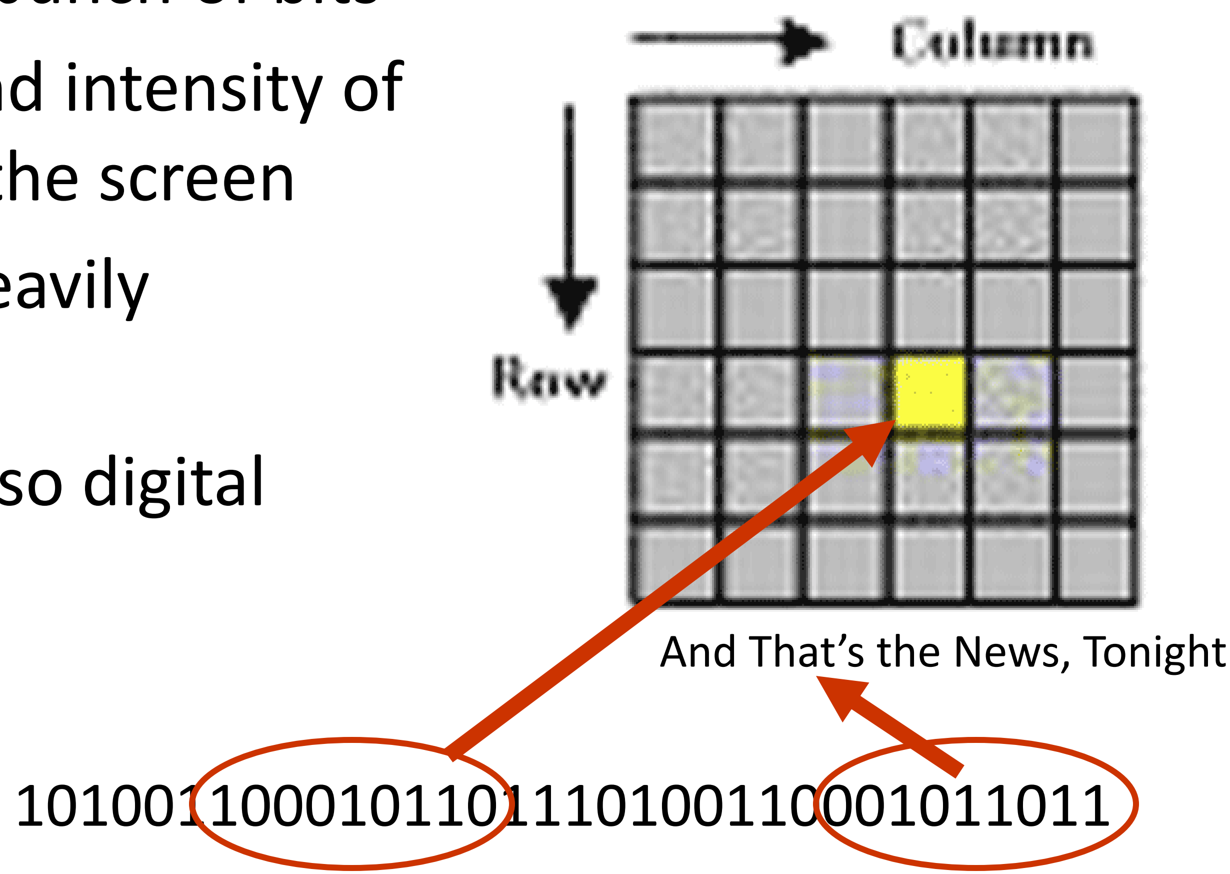
Analog TV



Captions are Contained as An analog Signal in the Vertical Blanking Interval

Digital TV

- Signal is just a bunch of bits
- Define color and intensity of each point on the screen
- Bit stream is heavily compressed
- Captions are also digital



Need to Understand

- What Will Work With What?
- What Will I Need?
- How to Connect your TV
  - Primary Source
  - DVDs and Tapes
- Controlling Captioning Options
  - Where Decoded
  - Appearance
  - Turning on/off
  - CC vs. Subtitles

What Will Work With What?

- Analog TV Will Continue To Work with
  - Cable Set Top Box (STB)
  - Satellite STB
  - Digital/Analog Converter (receive digital broadcasts via antenna)
  - Antenna will also receive analog broadcasts (until next year)
  - Current VCRs and DVDs will work (with some limitations)

- Digital HD TVs Will Work with
  - Cable (with or without STB)
  - Satellite STB
  - Antenna (if nearby digital stations exist)
  - Current and Future VCRs and DVDs (with some limitations)

For a Digital TV

- Monitor vs. TV (some older models don’t have a tuner)
- Plasma vs. LCD
- Projection vs. non-projection and DLP
- Refresh Rates
- Contrast Ratios
- But you WON’T need a Digital/Analog Converter
- Cable, or Satellite, or Antenna (if nearby digital broadcasts)
- STB for Satellite and (maybe) for Cable
- Connectors
- Optional: DVDs, VCRs, DVRs

For an Analog TV

- Must have at least one:
  - Cable (with STB)
  - Satellite (with STB)
  - Digital/Analog Converter and Antenna (and nearby digital stations)
- TV will still work from VCR or DVD even without those
- Picture may be quite a bit better, but it won't be HD
  - Depends on your TV
  - Depends on your connectors (S-Video is better than composite)
- Current and Future VCRs, DVDs and DVRs (with some limitations)

Digital/Analog Converters

- **What?: A Box that converts a digital signal to analog**

- **Why?: So analog TVs can display digital broadcasts**

- **Do I Really Need a D/A Converter?**
  - No: If you have Cable or Satellite or if all your TVs are digital (with tuners)
  - Yes: to receive Over the Air on an Analog TV after 17 Feb 2009

- **Reasons You May Want to Get a D/A Converter for Your Analog TVs**
  - Pictures on some analog TVs may actually look better than they do now.
  - Captions may look better on some programs
  - Using analog TVs as extra TVs without cable/satellite
  - Using analog TVs for emergencies or cable/satellite outages
  - Some local multi-casts may not be on cable/satellite

Connector Overview

- Coaxial Cable

From Cable, Satellite or Antenna to set top box or TV

- Composite

Yellow is video + Red and White for Audio

- S-Video

Carries Video with improved Quality

- Component

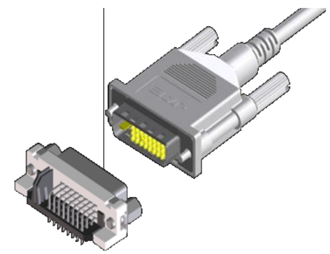
Red, Blue, Green (RGB) is Video, + Red and White for Audio
Digital quality and does captions

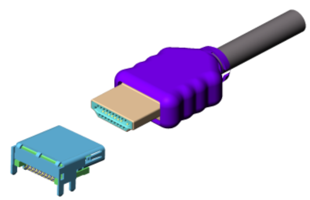
- HDI

Newest, Best all digital Video and audio,
but doesn’t do encoded captions

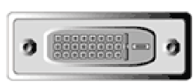
System Interfaces

- RF – NTSC
- RF – ATSC
- Baseband analog NTSC
  - Composite (CVBS)
  - S-Video (Y/C)
  - Component (YUV)
- Analog HD component (YPbPr)
- Analog PC graphics (VGA)
- Digital PC graphics (DVI-HDCP)
- Digital HD
  - DVI-HDCP [High Definition Content Protection] from PC space used by STBs and current generation of HD-Ready TV
  - HDMI - New CE version of DVI adds audio, video formats, control functions



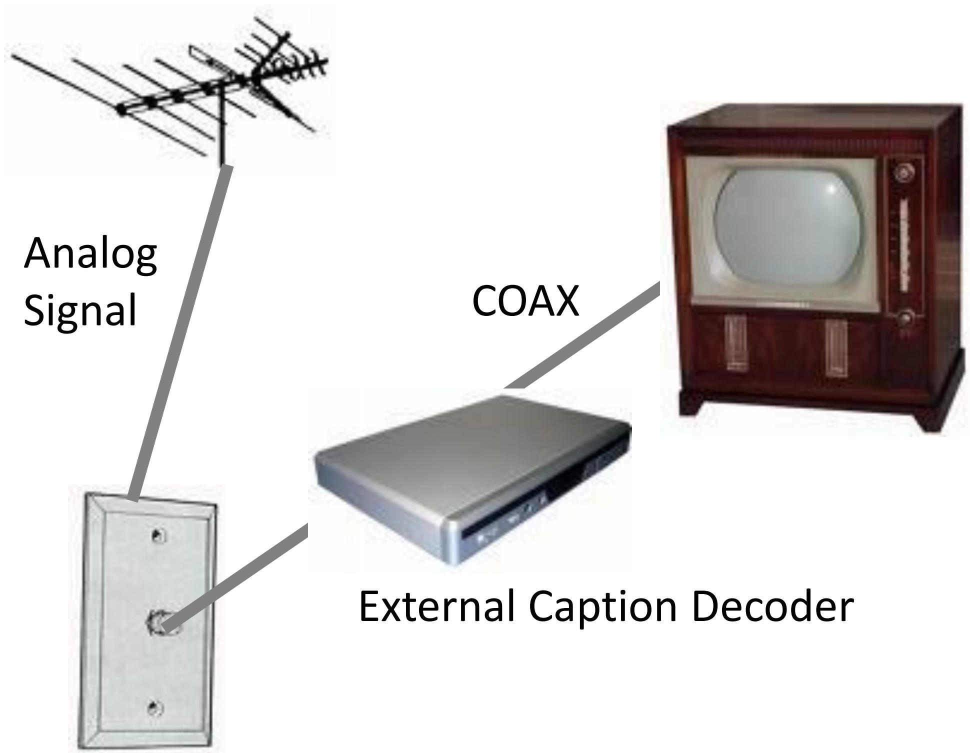


Connector Overview

- Antenna  Old connector for over the air; often now have Coax for Antenna
- Optical  No electronic interference, uses light (Audio Only)
- Firewire  For Computers and Video Cams but doesn't do captions
- DVI   DVI-D and DVI-I: Good all digital Video, but doesn't do captions
- VGA  Use your TV as a computer monitor
- USB  Commonly used to plug in digital cameras and see videos or slide shows
- Flash 

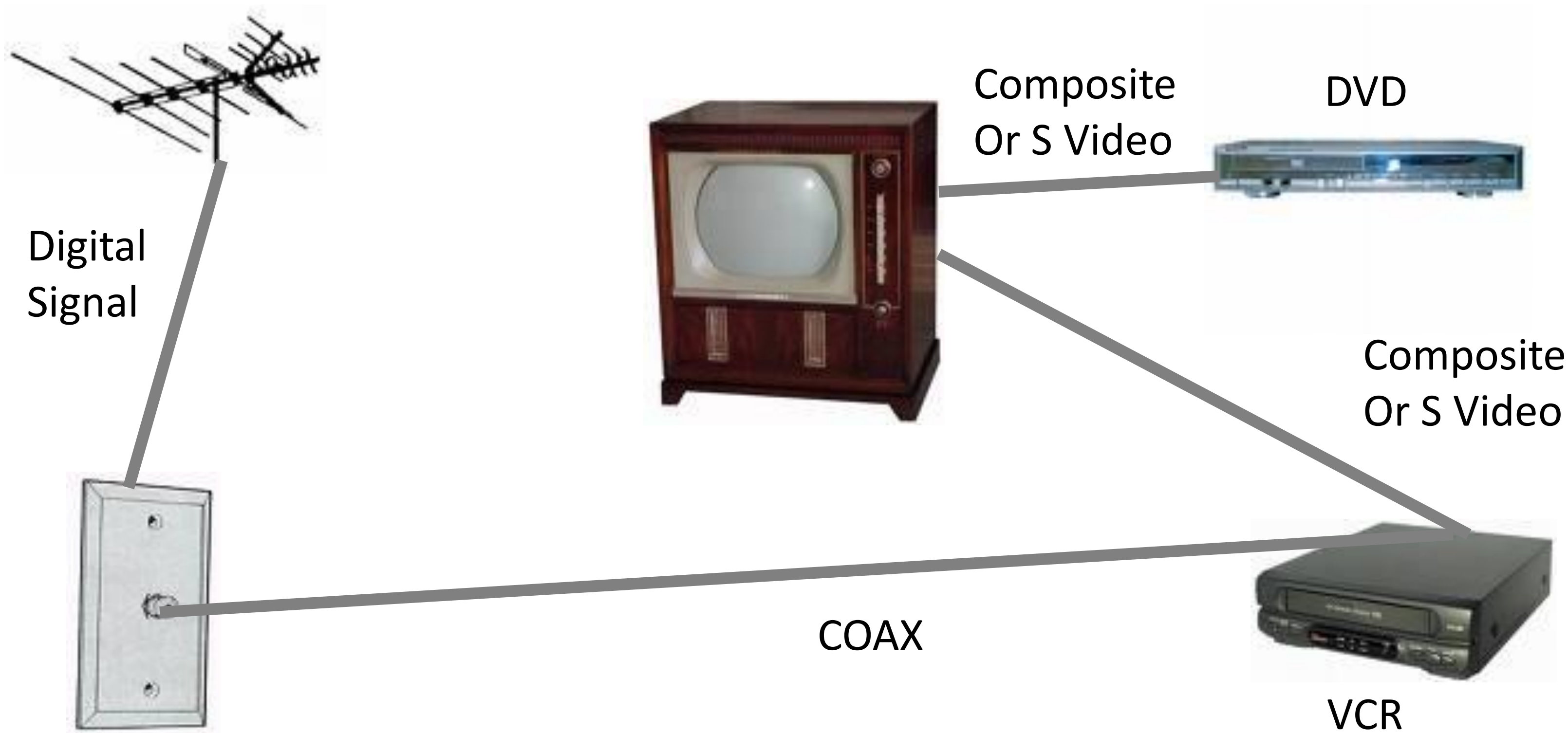

Some TVs may have slots for these for viewing photos or video clips

Connecting To Analog TV

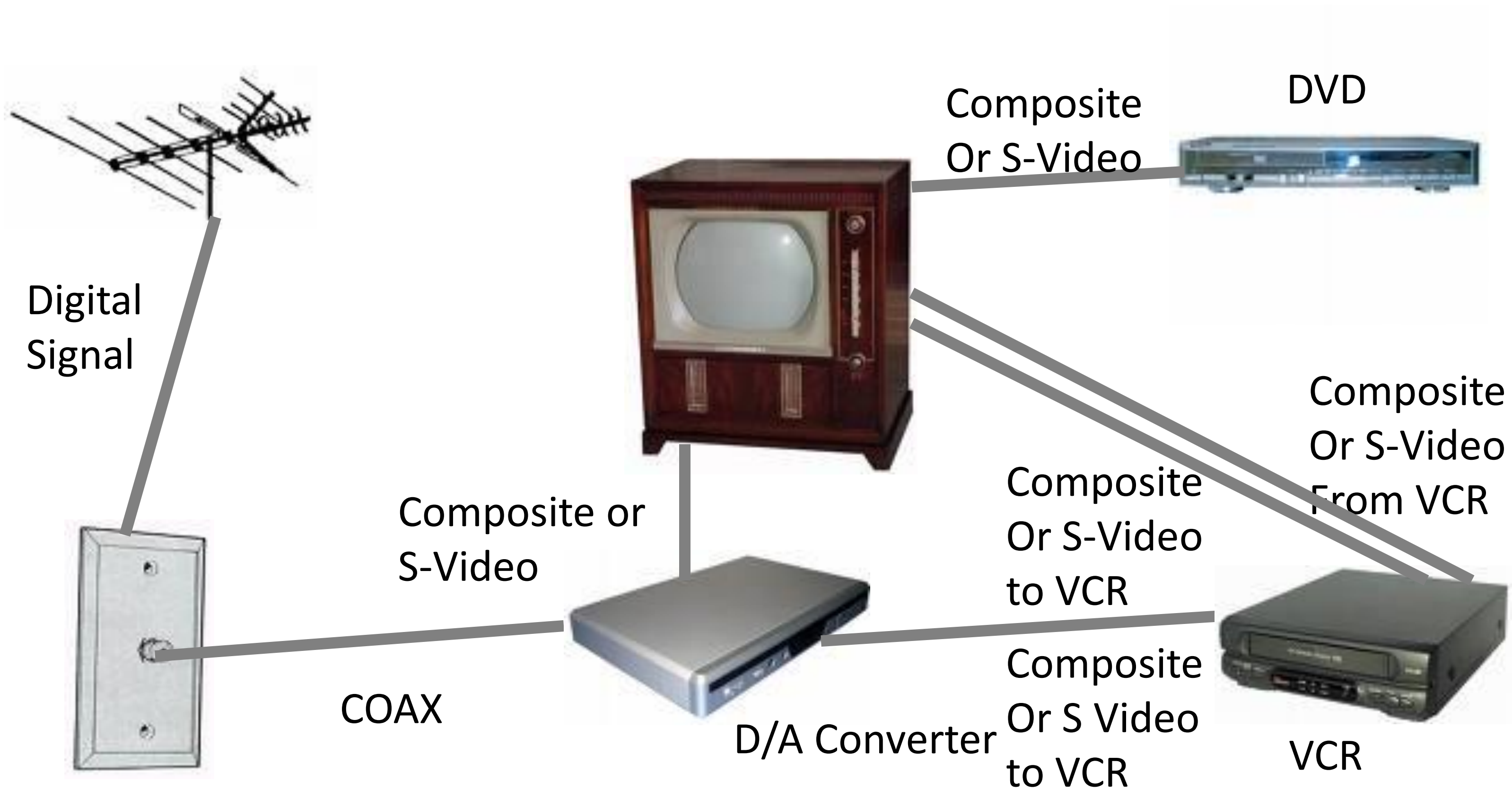


- Old or Small TVs without Caption Decoder Chip can Use an external Caption Decoder Box.

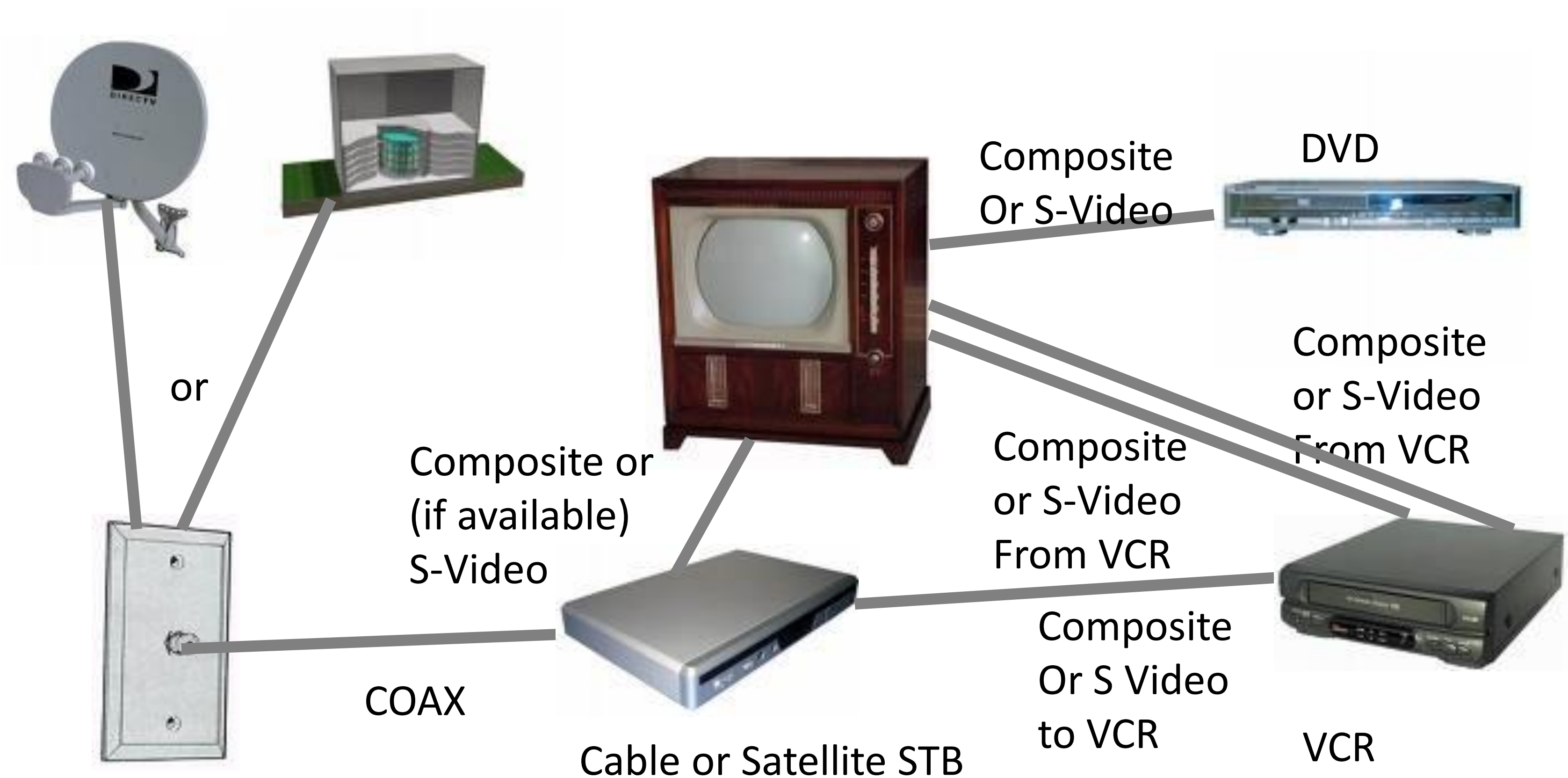
Connecting To Analog TV



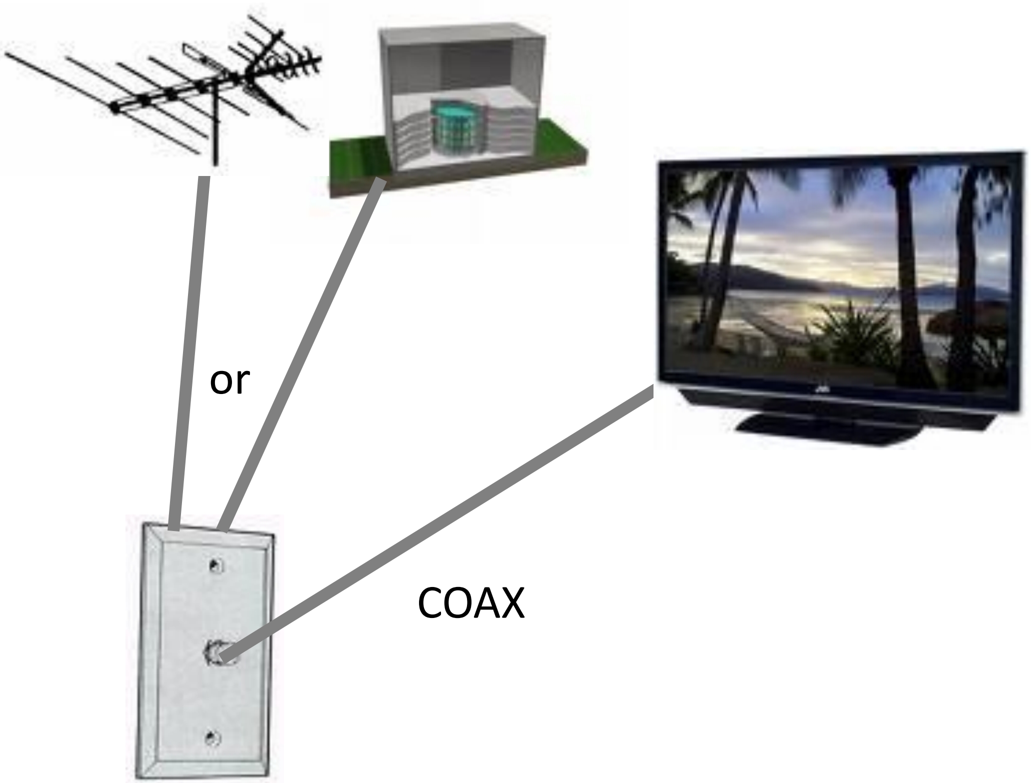
Connecting To Analog TV



Connecting To Analog TV

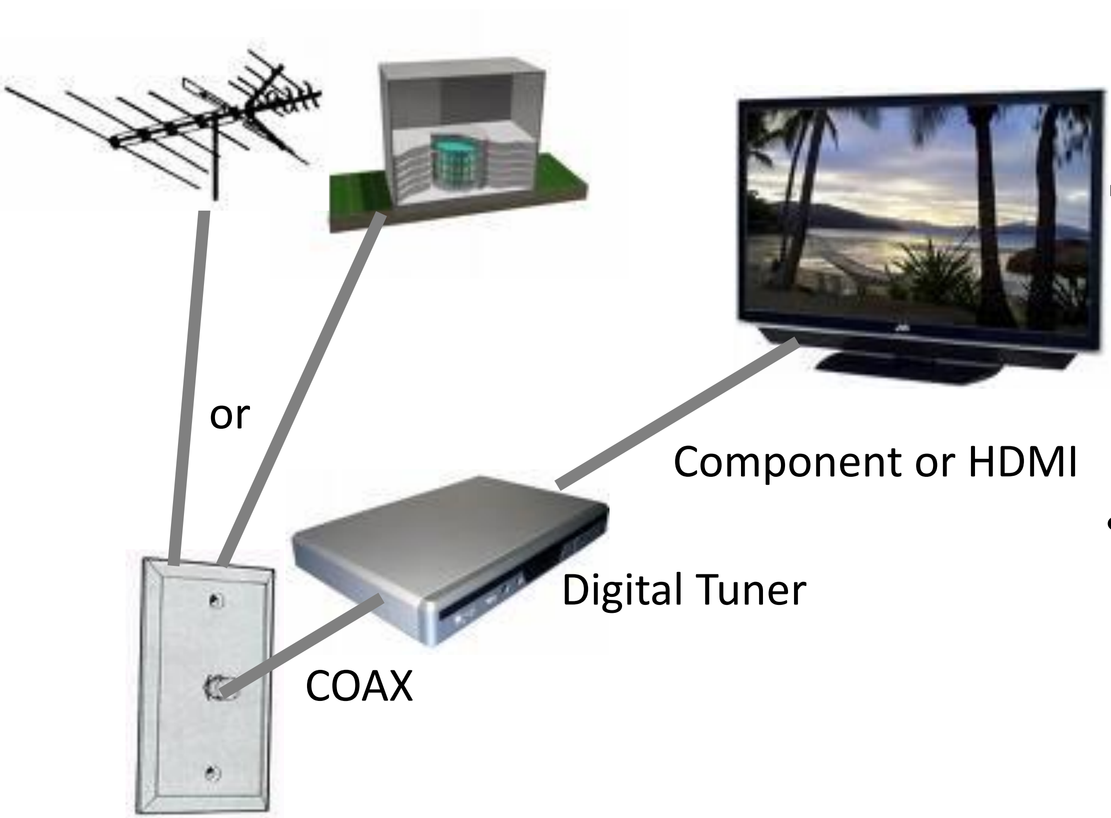


Connecting To Digital TV



- Digital TV with tuner (not just a “monitor” or “HD Ready” TV) can receive directly from antenna.
- Digital TV with QAM input can receive limited cable options without a Set Top Box

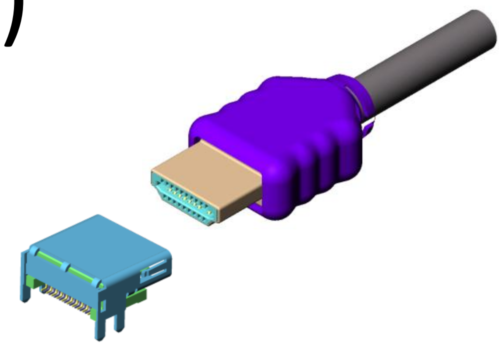
Connecting To Digital Monitor



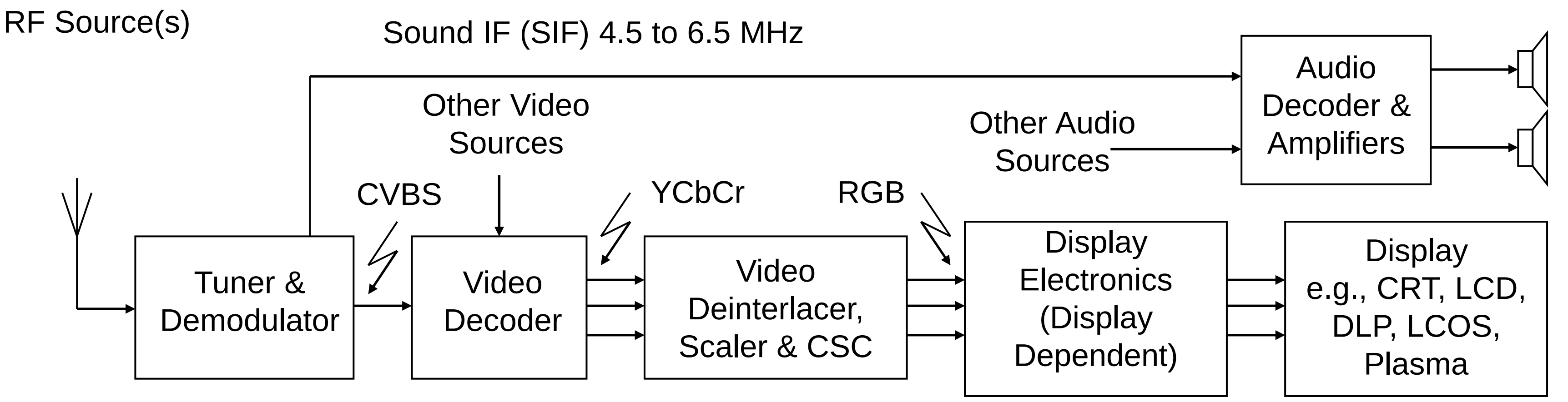
- Digital TVs without a Tuner (sometimes called "HD Ready" or a "Monitor") must have a digital tuner to receive digital signals.
- Indoor antenna may be enough in areas near a lot of digital stations.

High Definition Multimedia Interface (HDMI)

- HDMI is DVI plus
  - Audio
  - Support for YCbCr video
  - CE control bus
  - Additional control and configuration capabilities
  - Small CE-friendly connector
- HDMI enables device communication
  - To source
    - Supported video and audio formats
  - To display
    - Video and audio stream information

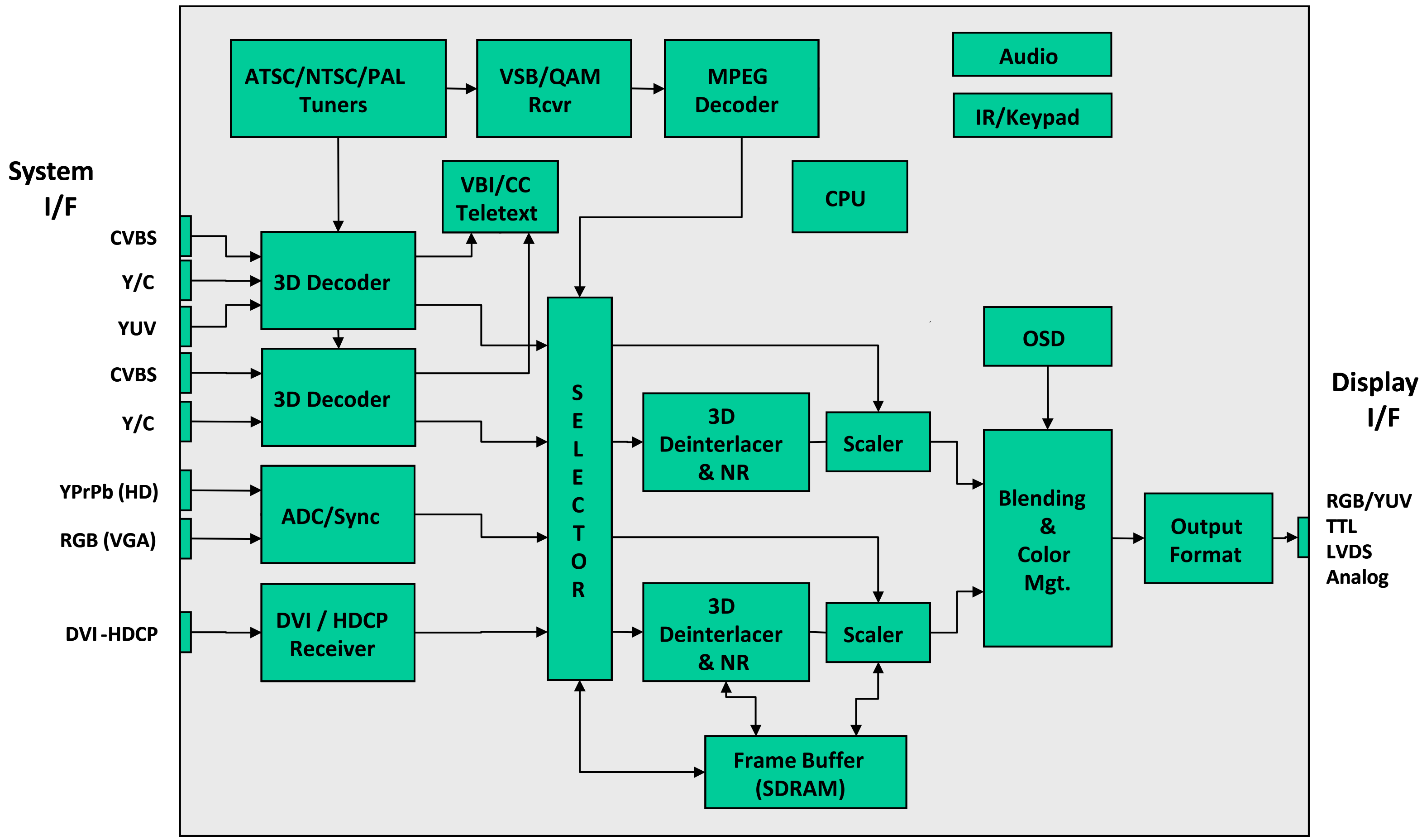


The Modern “HD Ready” TV Set



- **The tuner** extracts one TV channel at a time from many, then downconverts and demodulates the signal to “baseband”
- **The video (or “color”) decoder** separates the colors from the “composite” (CVBS) signal
- **The deinterlacer and scaler** converts the format of the picture to match that of the display type (optional for CRT TVs)
- **The display electronics** converts the signal format to match that of the display type: e.g. analog for CRT, LVDS for LCD panel

Functional System Architecture for MPEG TV



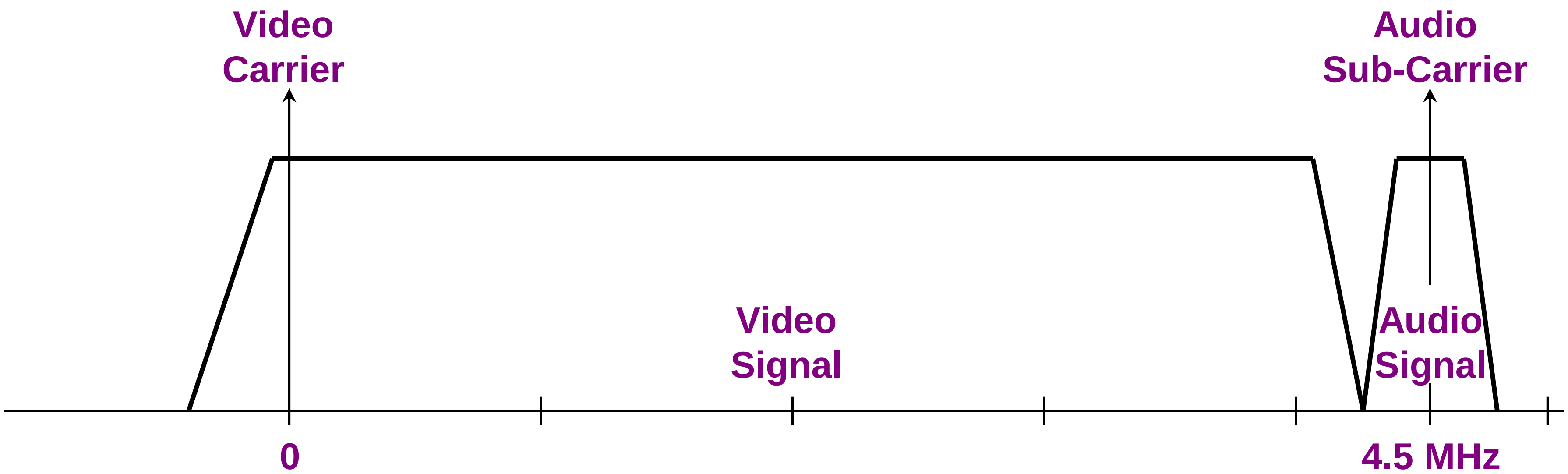
Color Television Systems

- Color TV systems developed in ’50s (NTSC) and ’60s (PAL)
- Backward compatibility with monochrome TVs more important than color quality!
  - Basic parameters of signal (carrier frequencies, bandwidths, modulation format, etc.) had to remain unchanged
- NTSC and PAL systems added chrominance (color) information to luminance (brightness) signal in a manner transparent to monochrome TVs

NTSC Fundamentals

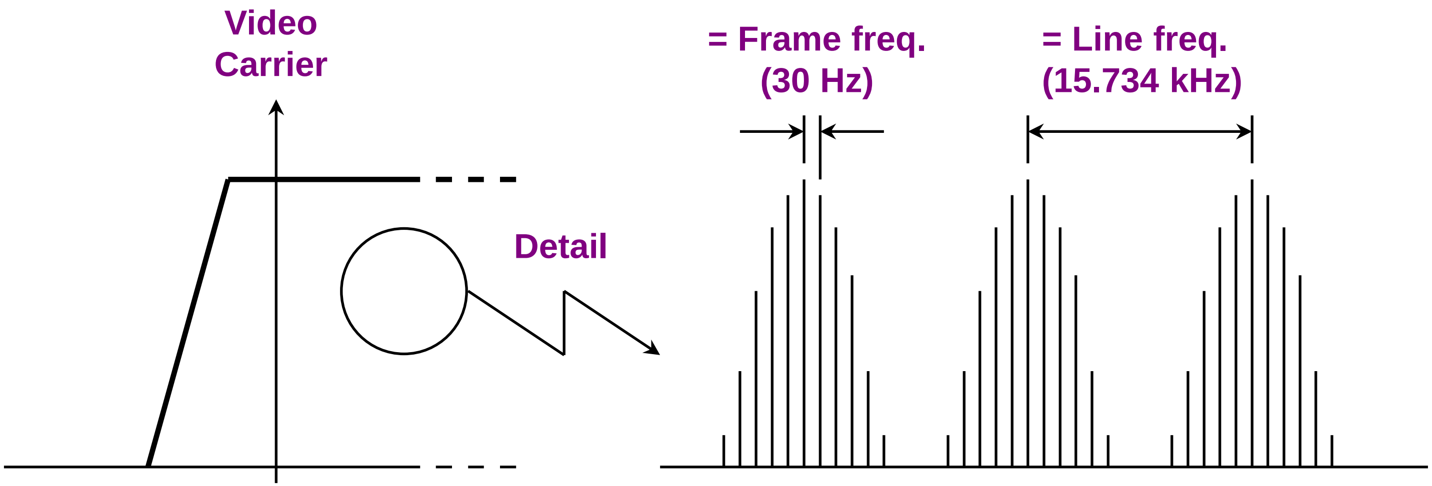
- **Approved in US by FCC in 1953 as color system compatible with existing 525 line, 60 fields/sec, 2:1 interlace monochrome system**
- **Color added to existing luminance structure by interleaving luma and chroma in frequency domain**
- **Basic properties**
  - **525 lines/frame**
  - **2:1 interlace → 2 fields/frame with 262.5 lines/field**
  - **Field rate 59.94 Hz**
  - **Line frequency (f_h) = 15.734 KHz**
  - **Chroma subcarrier frequency (f_{sc}) = 3.58MHz = 227.5 f_h = 119437.5 f_v**
    - **chosen so that consecutive lines and frames have opposite (180°) phase**
  - **Luma: Y = 0.299R' + 0.587 G' + 0.114 B', where R', G', B' are gamma-corrected R, G, B**
  - **Chroma: I (In-phase) and Q (Quadrature) used instead of color difference signals U, V**
    - **U = 0.492 (B'-Y), V = 0.877 (R'-Y)**
    - **I = V cos33° - U sin33°, Q = V sin33° + U cos33°**
  - **Composite = Y + Q sin(wt) + I cos(wt) + sync + blanking + color burst, where w = 2 pi f_{sc}**

Monochrome TV Signals (NTSC)



- In the NTSC monochrome system the luminance signal is AM/VSB (Amplitude Modulation/Vestigial Sideband) modulated onto the video carrier
- The sound signal is FM modulated onto the Audio Sub-Carrier located 4.5 MHz from the video carrier

Spectrum of Monochrome TV Signal (NTSC)



- Spectrum of the video extends from just below the video carrier frequency to just below the sound carrier
- Repetitive nature of the signal from line to line and frame to frame results in a “picket-fence”, or comb, spectrum

Color in Video

- In PC space, R+G+B signals generate color images
- In video space, color signals developed for backward compatibility with monochrome TVs
  - Image brightness represented by luma signal (Y), equivalent of monochrome TV signal
  - Color added with “color difference” signals: Cb and Cr
  - Matrix equation translates color spaces
    - Y (luma) = 0.299R' + 0.587G' + 0.114B'
    - Cb (blue chroma) = 0.492(B'-Y)
    - Cr (red chroma) = 0.877(R'-Y)

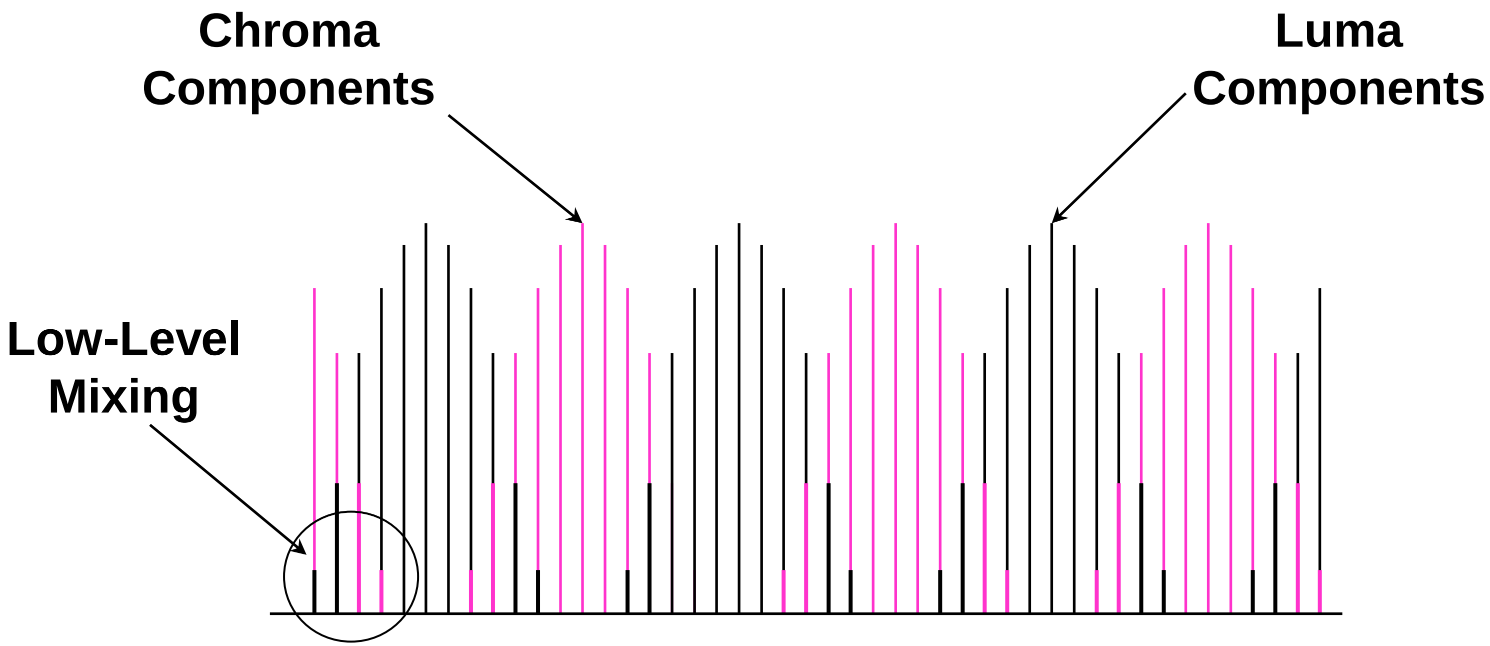
Principles of NTSC Color System

- Takes advantage of spectral nature of luminance signal
- Recognizes human eye is less sensitive to color changes than luma changes
- Low bandwidth chrominance information is modulated onto a Color Sub-Carrier and added to the luma signal
- The chroma signal has a picket-fence spectrum
  - sub-carrier frequency very carefully chosen so of the chroma signal pickets are interlaced between those of the luma signal
  - $f_{SC} = 227.5 \times f_H = 3.579545$ MHz

Why a weird number like 59.94 Hz?

- Early TV systems used local power line frequency as the field rate reference
- Europe used 50 Hz, the USA used 60 Hz
- With the introduction of color, audio subcarrier frequency required integer relationship to color subcarrier to prevent interference
  - Nearest value to the original 4.500 MHz was 4.5045 MHz, too large a difference for backward compatibility
- Reducing field rate from 60 to 59.94 Hz, allowed integer value of 4.49999 MHz possible for audio subcarrier
  - This is close enough, solving the problem

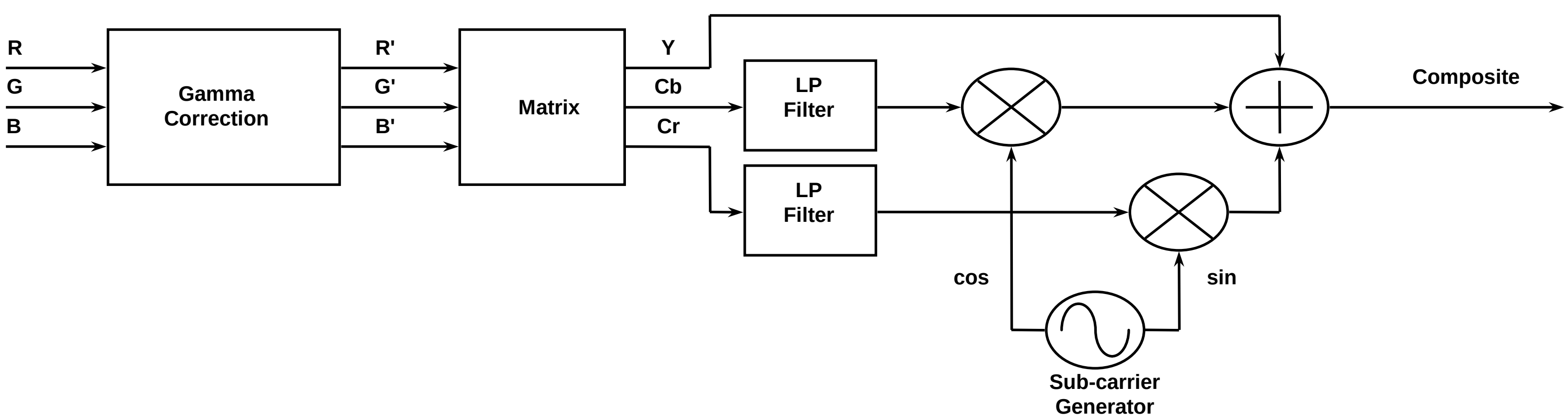
The Result



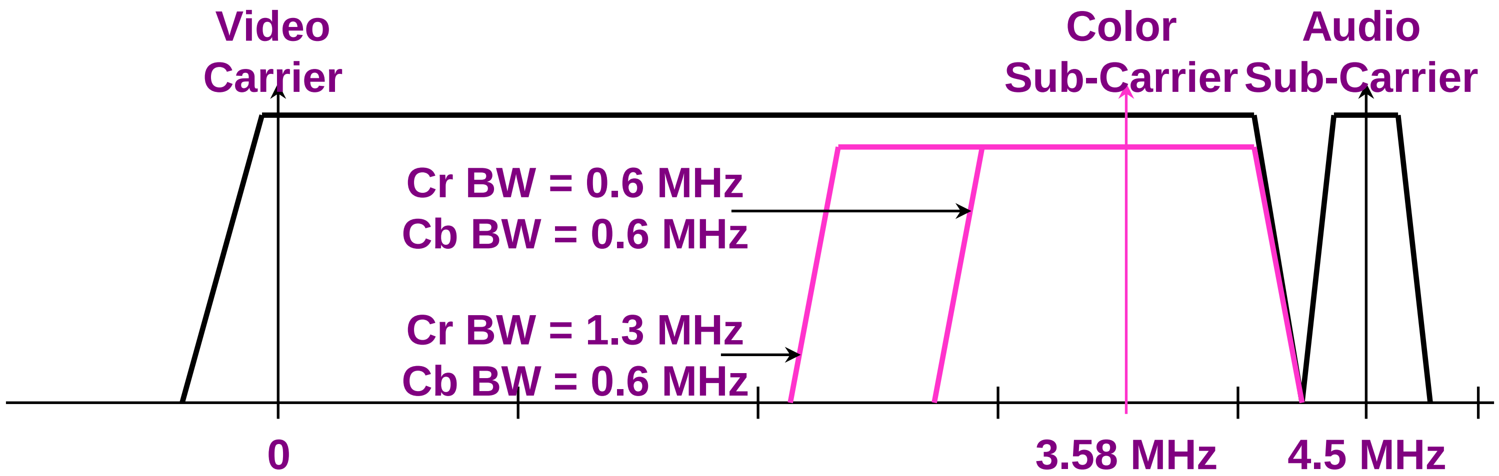
- The chroma components can be mostly separated from the luma with a comb filter
- Note the mixing of lower-level luma and chroma components, resulting in residual cross-luma and cross-color artifacts

Implementation of NTSC Color

- Gamma correction applied to adjust for CRT non-linearity of Component color signals (R', G' and B') are converted to luma and chroma-difference signals with a matrix circuit:
- Cb and Cr are lowpass filtered, then quadrature modulated (QAM) onto the chroma sub-carrier
  - Signal Amplitude represents the color saturation of video
  - Phase represents the hue
  - Chroma levels chosen such that peak level of composite signal does not exceed 100 IRE with 75% color bars

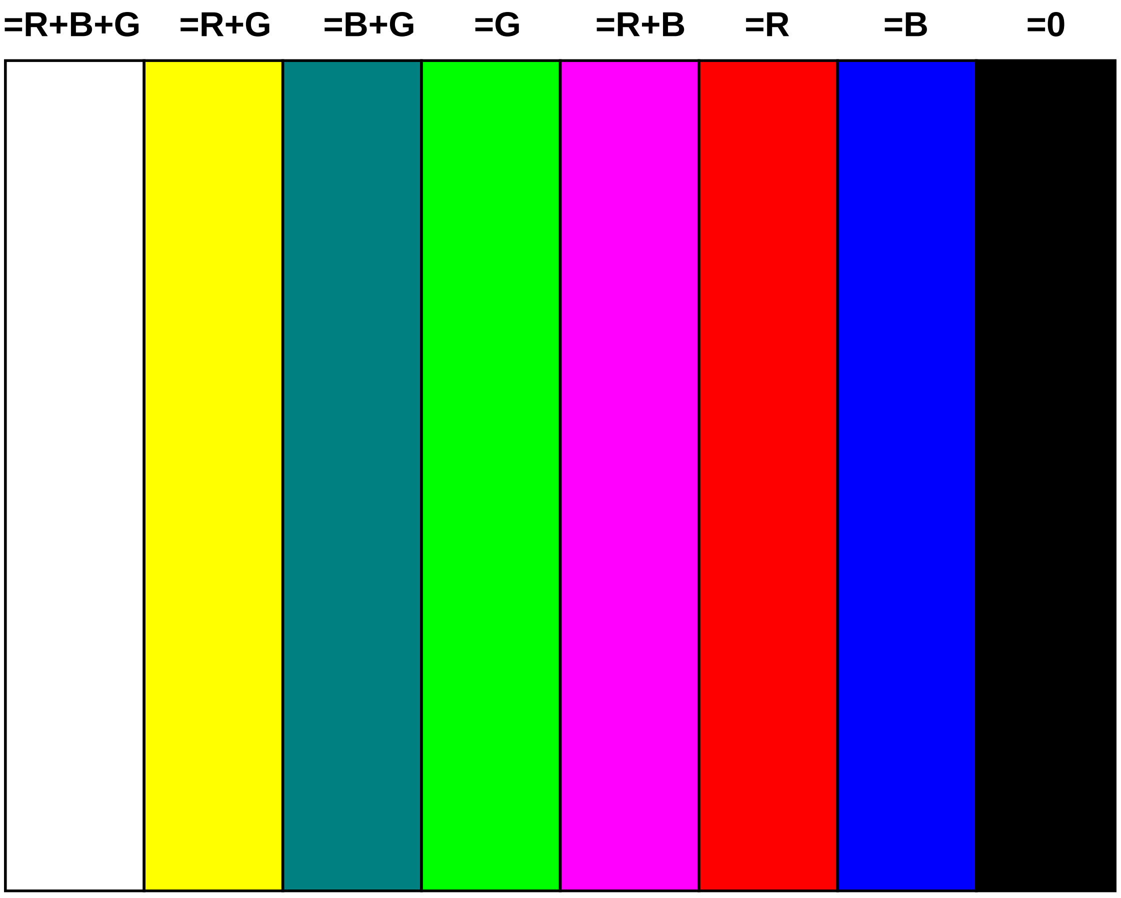


Spectrum of the NTSC Color Signal



- Full chroma signal bandwidth, ±1.3 MHz around sub-carrier, too wide for transmission within channel allocation
- Usually, both Cb and Cr bandwidths are reduced to 600 kHz
  - Reduces cross-color and cross-luma in TV
- Alternatively, compliant to true NTSC specification:
  - Cb component (only) can be band-limited to 600 kHz
  - Phase of sub-carrier rotated by 33°, puts flesh tones at around 0°
  - Results in asymmetrical signal (shown)
  - The rotation aligns flesh tones to the I axis and is transparent to demodulator since color-burst is rotated by same amount

The NTSC Color Video signal
(EIA 75% color bar signal)



NTSC Color Video Signal

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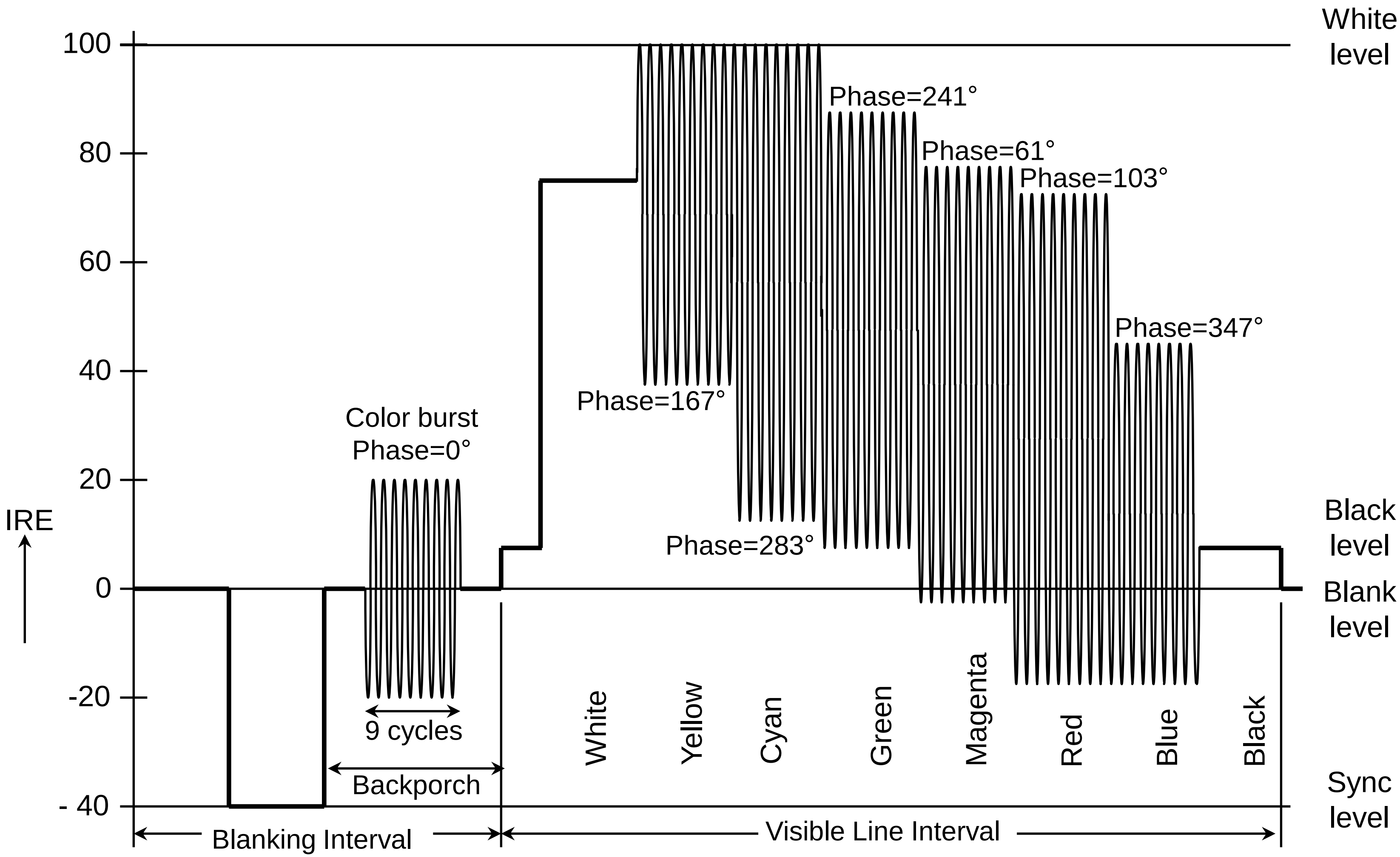


PAL Fundamentals

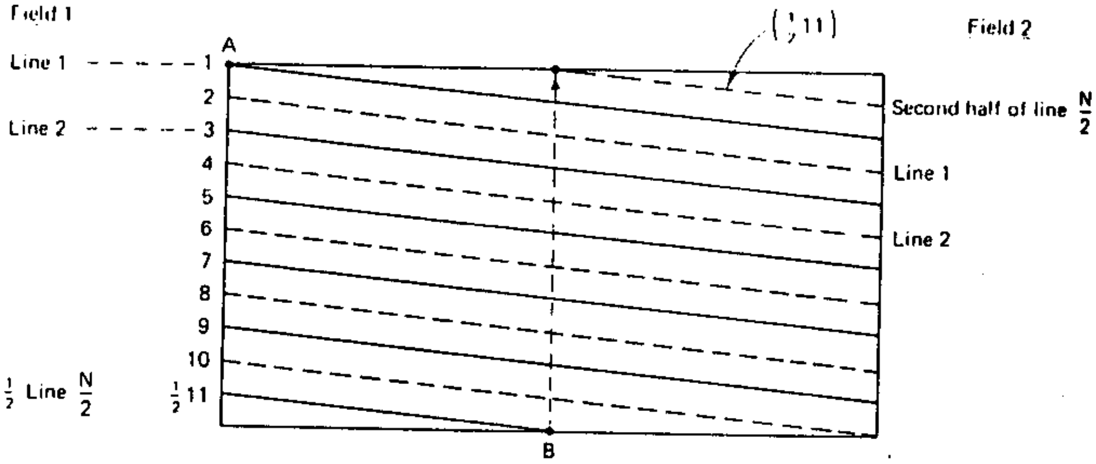
- **European standard with many flavors - broadcasting begun in 1967 in Germany and UK.**
- **Similar in concept to NTSC, except that line and field timings are different, and the phase of the V (chroma) component is reversed every line to allow color phase errors to be averaged out**
- **Basic properties (except for PAL-M which has NTSC like rates)**
  - **625 lines/frame**
  - **2:1 interlace → 2 fields/frame with 312.5 lines/field**
  - **Field rate 50 Hz**
  - **Line frequency (f_h) = 15.625 KHz**
  - **Chroma subcarrier frequency (f_{sc}) = 4.43MHz = (1135/4 + 1/625) f_h**
    - **consecutive lines and frames have 90^o phase shift, so 2 lines or 2 frames required for opposite phase**
  - **Luma: Y = 0.299R' + 0.587 G' + 0.114 B', where R', G', B' are gamma-corrected R, G, B**
  - **Chroma: Usual color difference signals U, V**
    - **U = 0.492 (B'-Y), V = 0.877 (R'-Y)**
  - **Composite = Y + U sin(wt) +/- V cos(wt) + sync + blanking + color burst, where w = 2 pi f_{sc}**

SECAM Fundamentals

- Developed in France - broadcasting begun in 1967
- Basic timing is identical to PAL but chroma is handled differently from NTSC/PAL
  - Only one chroma component per line
  - FM modulation is used to transmit chroma
- Basic properties
  - 625 lines/frame
  - 2:1 interlace → 2 fields/frame with 312.5 lines/field
  - Field rate 50 Hz
  - Line frequency (f_h) = 15.625 KHz
  - Luma: Y = 0.299R' + 0.587 G' + 0.114 B', where R', G', B' are gamma-corrected R, G, B
  - Chroma: Scaled color difference signals U, V
    - Db = 1.505 (B'-Y), Dr = -1.902 (R'-Y)
    - only one chroma component per line, alternating between Dr, Db
    - separate subcarriers for Dr, Db

Composite Video: NTSC / PAL / SECAM

- **Long-time world television standards**
- **Basic properties**
  - **Analog interlaced scanning**
    - **3D (H,V,T) information expressed as a 1D (temporal) raster scanned signal**
    - **Each picture (frame) displayed as 2 interleaved fields - odd + even**
  - **Luminance (Y) and Chrominance (R-Y, B-Y), sync, blanking, and color reference information all combined into one "composite" signal**



Luma/Chroma Separation

- Many approaches trading off complexity, cost and performance
  - Basic approaches (historical)
    - Low pass luma / high pass chroma
    - Notch luma / bandpass chroma
  - Advanced approaches (commonly used in most systems today)
    - 2D passive line comb filter
    - 2D adaptive line comb filter
    - 3D (spatio-temporal) comb filter
- Decoding artifacts
  - Loss of resolution
  - Dot-crawl
  - Cross-color
- Good decoding requires some black magic (art) because luma and chroma spectrums overlap in real motion video

S-Video Signals

S-Video was developed in conjunction with the S-VHS VCR standard, where the luma and chroma signals are kept separate after initial Y/C separation

– Keeping the signals separate, i.e. never adding the luma and chroma back together, eliminates the NTSC artifacts

– Since video sources are generally composite (NTSC), the full benefit is not realized

– Keeping the signals separate after playback with the VCR does help, especially because of the timing jitter

Luma and Chroma Signal Separation (Y/C Separation)

The chroma signal (C) is separated from the composite signal by filtering

- Adaptive comb filtering is required for high quality
  - Low cost TVs use a bandpass filter, resulting in incomplete separation and bad cross luma and chroma artifacts
  - Non-adaptive comb filters introduce problems at edges

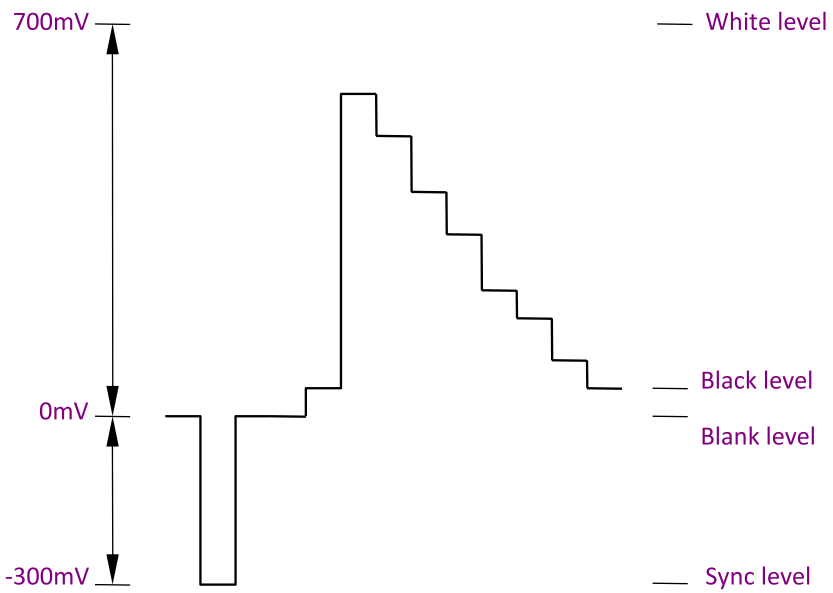
The luma signal (Y) may be derived by subtracting

the chroma from the composite signal

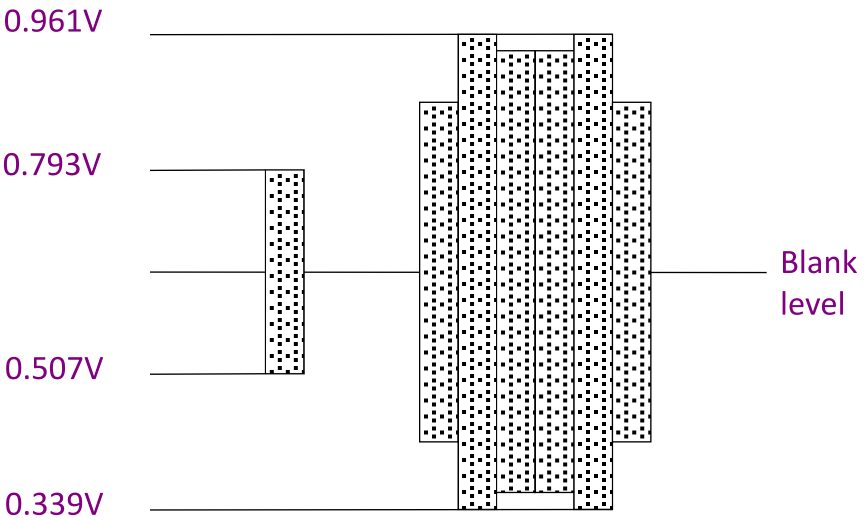
- Only works well if the chroma was separated well
- Low cost TVs use a bandstop filter to eliminate the chroma, resulting in poor luma bandwidth

NTSC Color Video signal after Y/C Separation

(EIA 75% color bar signal)

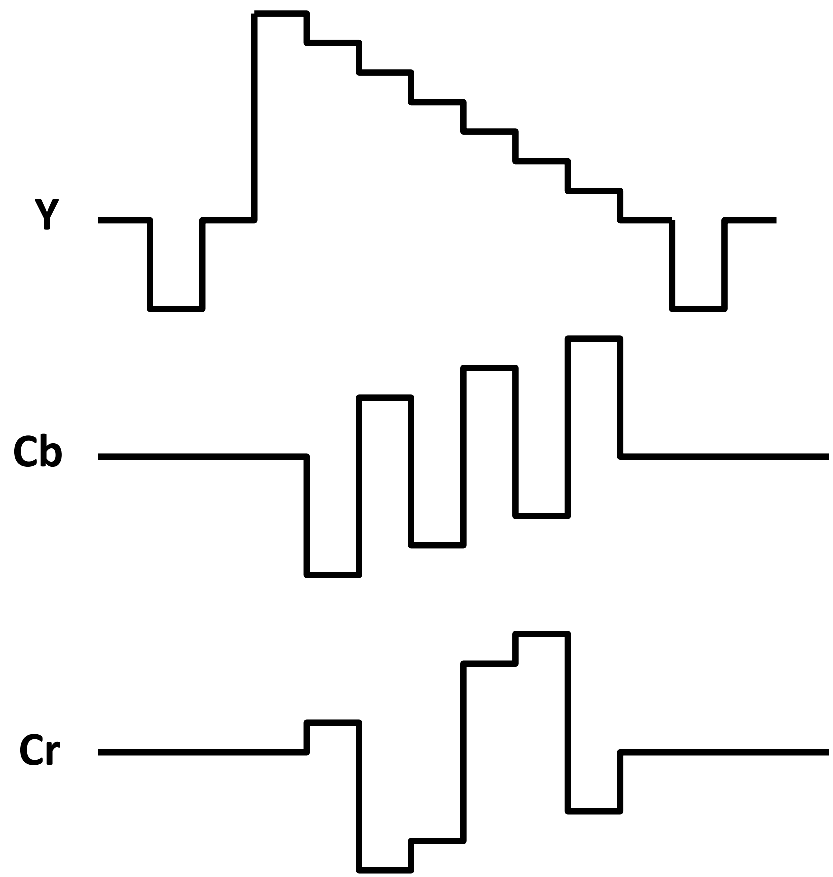


Luma



Chroma

The NTSC Color Video signal after chroma demodulation (EIA 75% color bar signal)



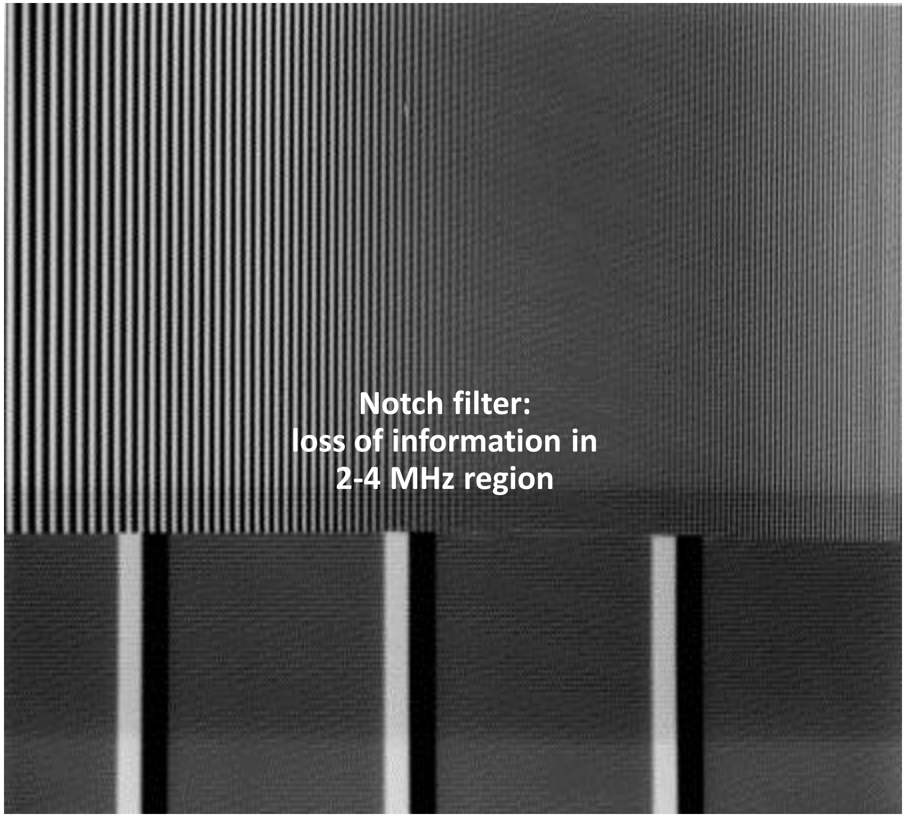
Chroma Demodulation

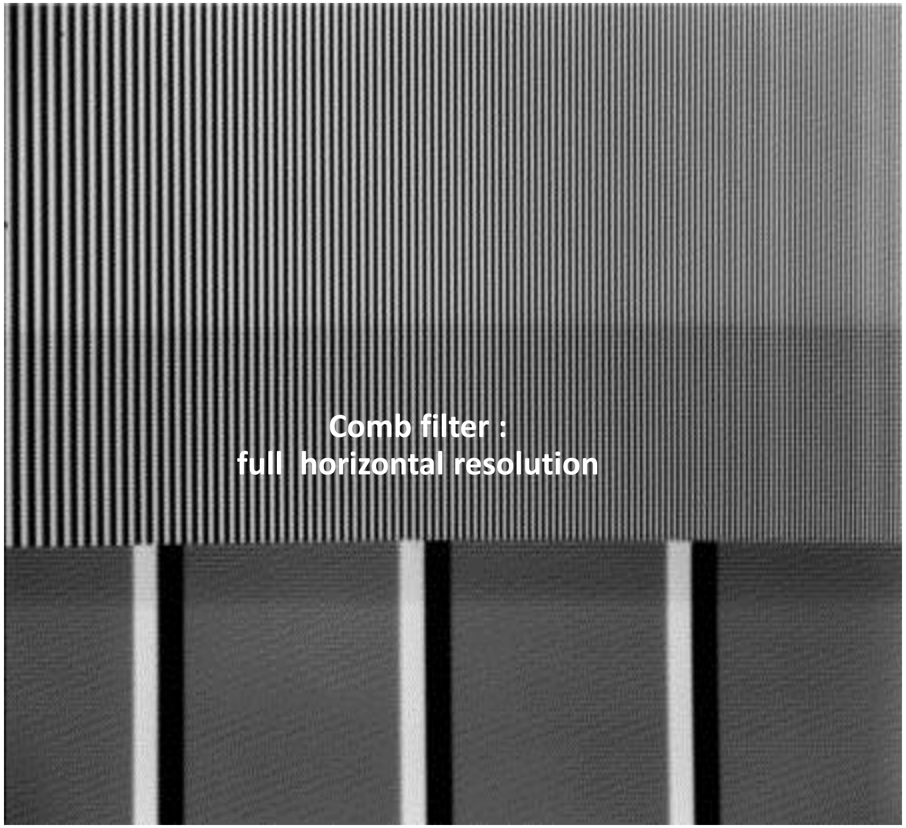
- The Cb and Cr color difference signals are recovered by coherent demodulation of the QAM chroma signal

- An absolute phase reference is provided to facilitate the process
  - A color burst - 9 cycles of unmodulated color sub-carrier – is added between the horizontal sync pulses and the start of the active video (the “backporch”)

Notch/LPF versus Comb Filtering

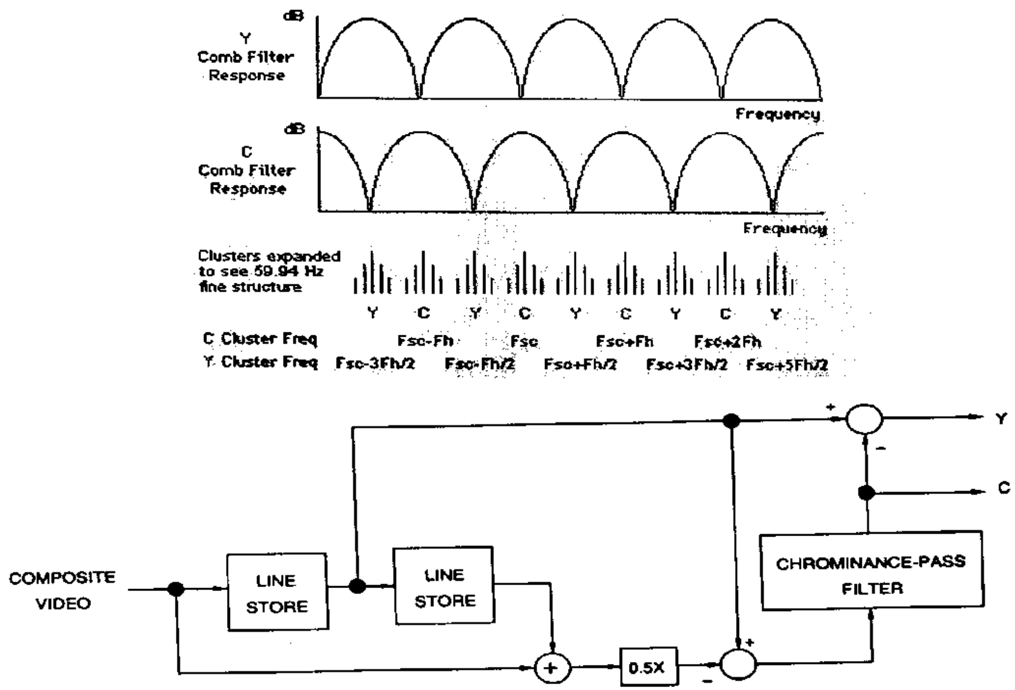
- **Comb filtering allows full bandwidth decoding**





Comb Filtering (cont.)

- Use 1 or more lines for each delay element, e.g., for NTSC, D = 1 line = 910 z^{-1}
- Apply "cos" version with positive coefficients to extract chroma or "sin" version with negative center coefficient to extract luma



Y/C separation using simple 2D passive comb

HDTV Technical Overview

- **Video:**
  - MPEG2 Main Profile @ High Level (MP@HL)
  - 18 formats: 6 HD, 12 SD
- **Audio:**
  - Dolby AC-3
- **Transport:**
  - Subset of MPEG2
  - Fixed length 188-byte packets
- **RF/Transmission:**
  - Terrestrial:
    - 8-VSB (Vestigial Side Band) with Trellis coding
    - effective payload of ~19.3 Mb/s (18.9 Mb/s used for video)
  - Cable:
    - Uses QAM instead of VSB
    - effective payload of ~38.6 Mb/s

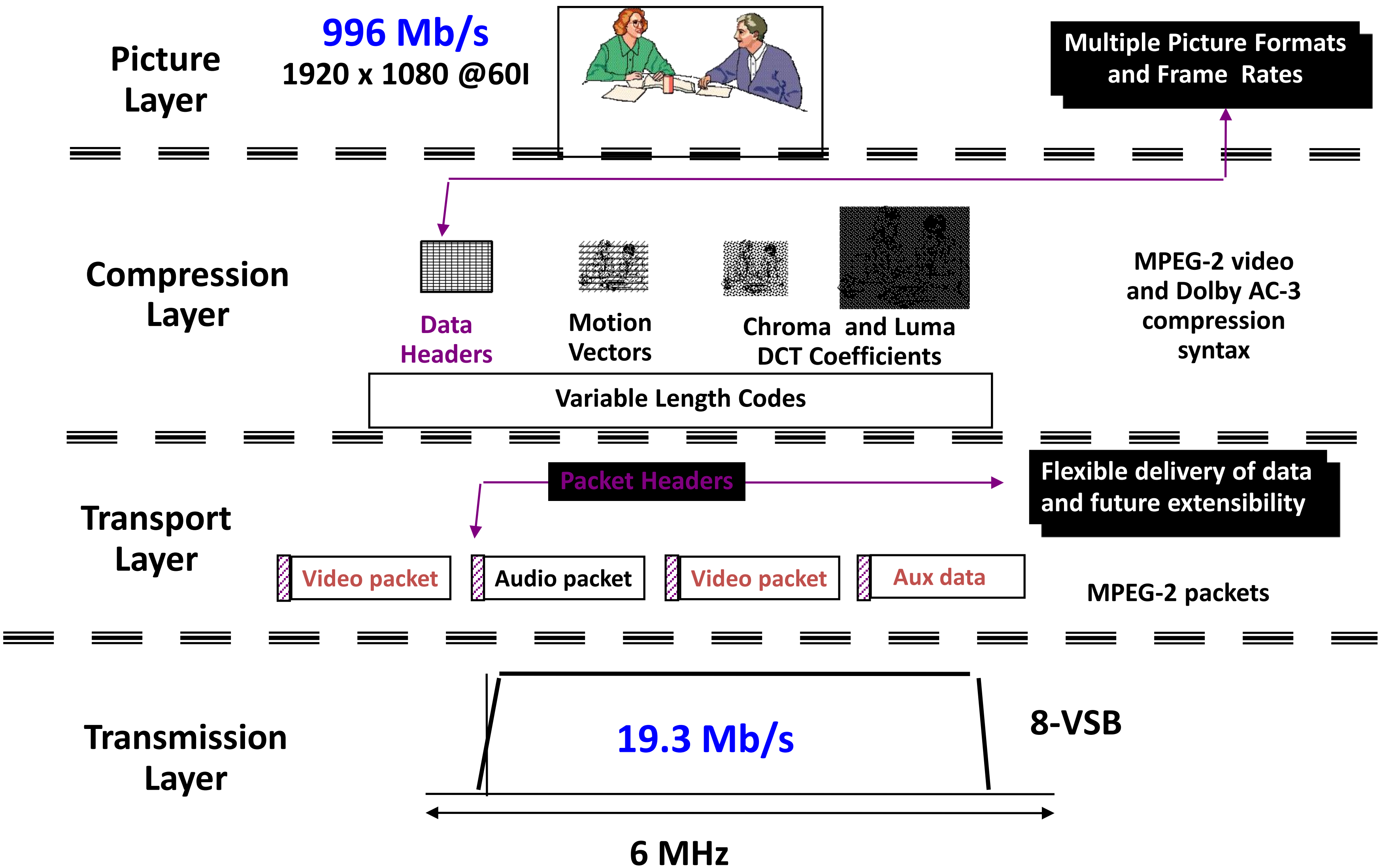
ATSC Formats

	Vertical	Horizontal	Aspect Ratio	Picture Rate
HDTV	1080	1920	16:9	60I, 30P, 24P
	720	1280	16:9	60P, 30P, 24P
SDTV	480	704	16:9 & 4:3	60P, 60I, 30P, 24P
	480	640	4:3	60P, 60I, 30P, 24P

- 18 formats: 6 HD, 12 SD
  - 720 vertical lines and above considered High Definition
  - Choice of supported formats left voluntary due to disagreement between broadcasters and computer industry
    - Computer industry led by Microsoft wanted exclusion of interlace and initially use of only those formats which leave bandwidth for data services - “HD0” subset
  - Different picture rates depending on motion content of application
    - 24 frames/sec for film
    - 30 frames/sec for news and live coverage
    - 60 fields/sec, 60 frames/sec for sports and other fast action content
- 1920 x 1080 @ 60 frames/sec not included because it requires ~100:1 compression to fit in 19.3 Mb/s terrestrial channel, which cannot be done at high quality with MPEG2

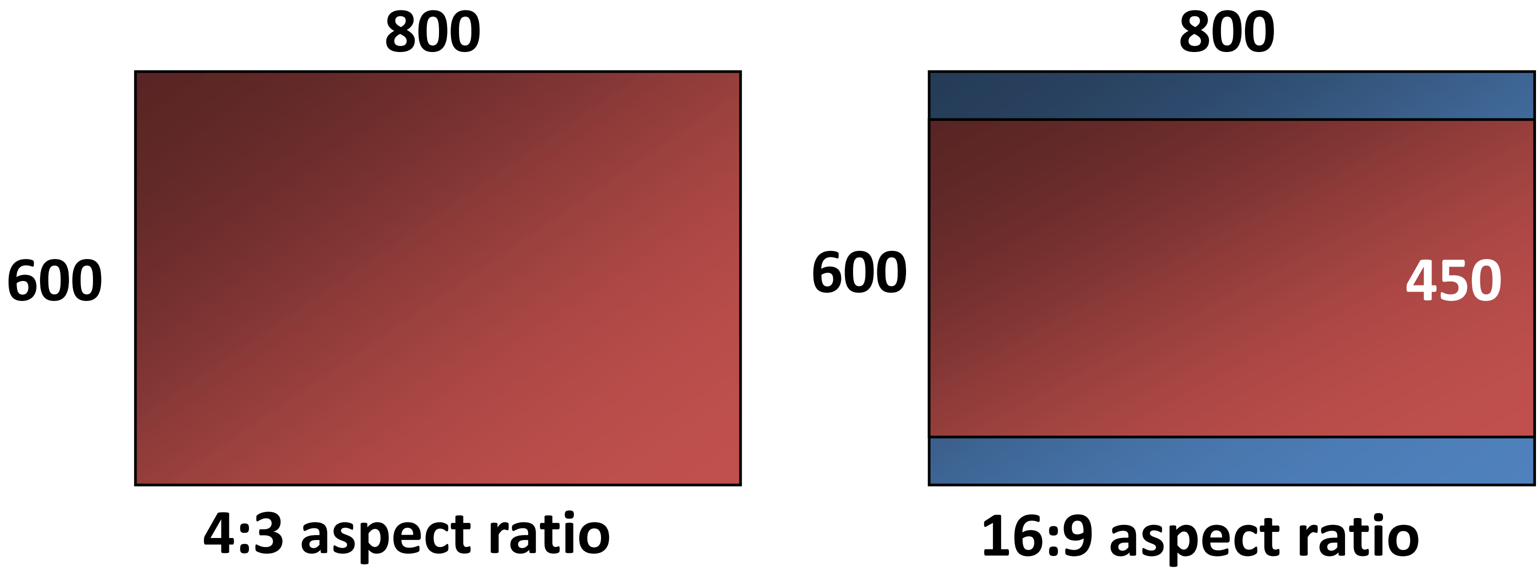
HDTV/DTV System Layers

layered system with header/descriptors



Aspect Ratios

- **Two options: 16:9 and 4:3**
- **4:3 standard aspect ratio for US TV and computer monitors**
- **HD formats are 16:9**
  - **better match with cinema aspect ratio**
  - **better match for aspect ratio of human visual system**
  - **better for some text/graphics tasks**
    - **allows side-by-side viewing of 2 pages**



Additive White Gaussian Noise

- **Ubiquitous in any electronics systems where analog is present**
  - **Central Limit Theorem explains the underlying cause**
- **Noise can be dramatically reduced by motion-adaptive recursive filtering ("3D NR")**
- **Basic equation:**

  Yi = X + Zi
  where Zi = measurement at time I, X = original data
  Wi = noise at time i = Gaussian white noise with zero mean

  MMSE estimate for N measurements = Σ(Yi)/N

- **Compute Average over same pixel location in each frame**
- **Noise averages to zero over a period of time**
- **Since averaging pixels that are in motion produces tails, we need reduce or stop averaging when there is motion**

AWGN - Example

Original

With Gaussian noise

After noise removal

Impulse Noise Reduction

- **Use nonlinear spatial filtering to remove impulsive noise without reducing resolution**

Original

After noise removal

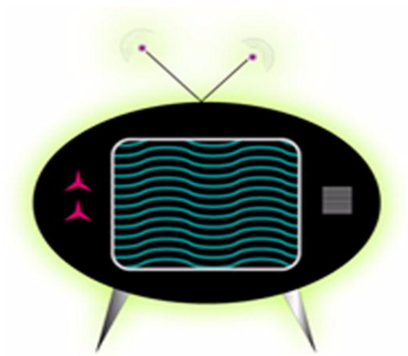
With impulse noise

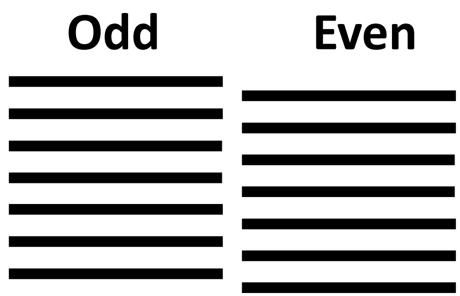
Digital (MPEG) Noise

- **Block Noise**
  - **Tiling effect caused by having different DC coefficients for neighboring 8x8 blocks of pixels**
- **Mosquito Noise**
  - **Ringing around sharp edges caused by removal of high-frequency coefficients**
- **Noise reduction is achieved by using adaptive filtering**
  - **Different choice of filters across block boundaries versus within blocks**

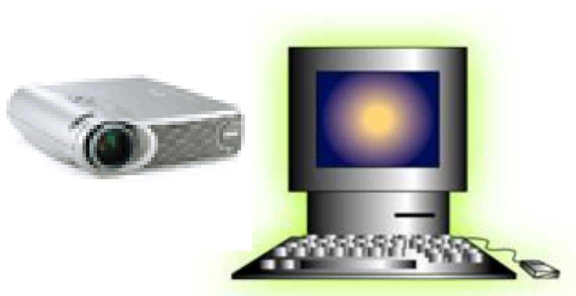
Deinterlacing (Line Doubling)

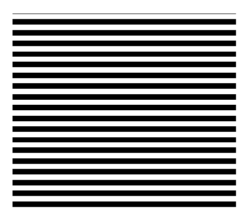
- Conversion of interlaced (alternate line) fields into progressive (every line) frames
- Required to present interlaced TV material on progressive display





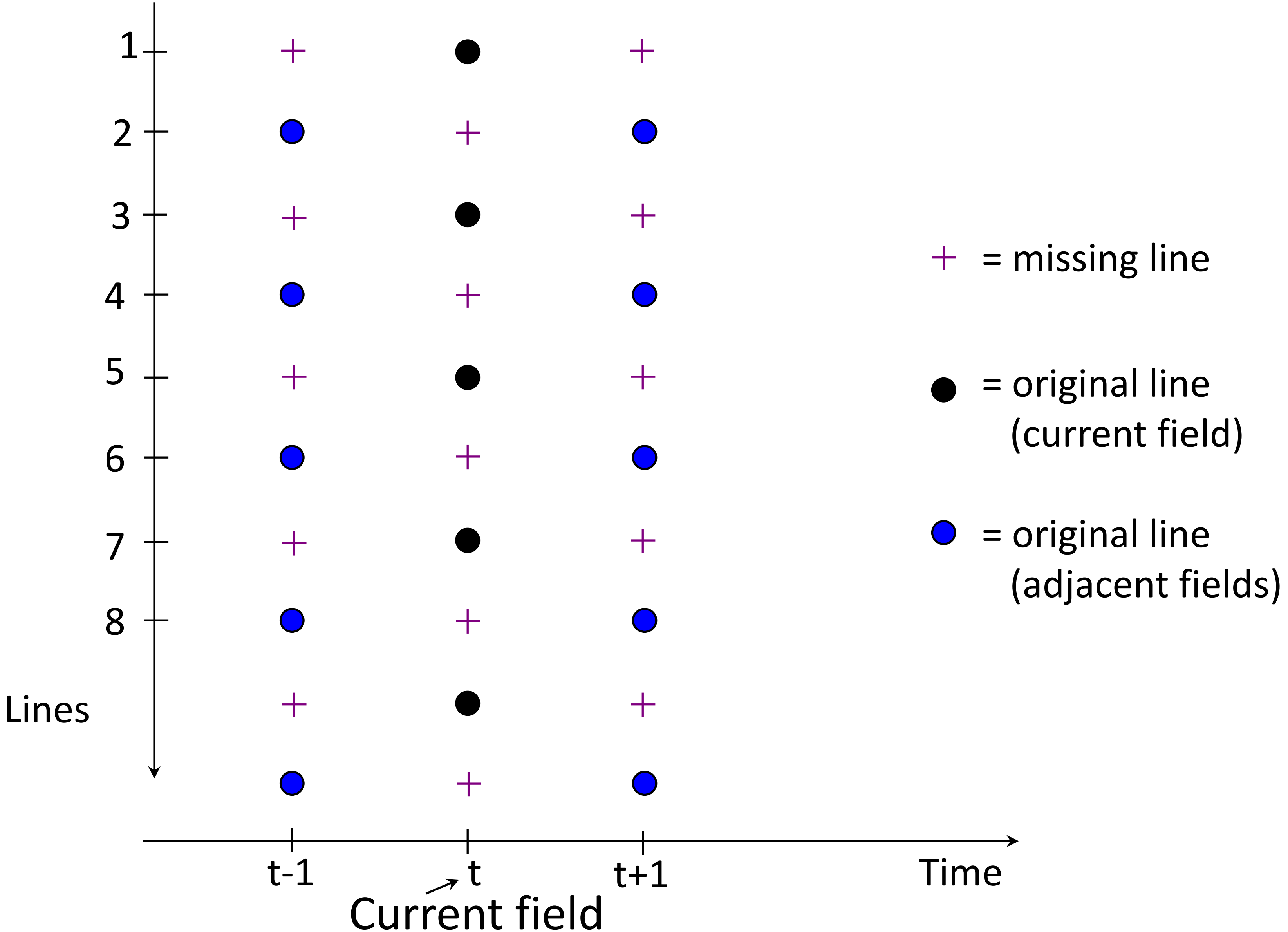
CRT-TV uses Interlaced scanning, with odd lines first followed by even lines





PC Monitor and all digital displays are Progressive - scanning all lines in consecutive order

Vertical-Temporal Progression



Interlacing and Deinterlacing Artifacts

- **Interlacing artifacts**
  - Twitter
  - Wide-area flicker
  - Temporal aliasing
  - Line Crawl
- **Deinterlacing artifacts**
  - Feathering/ghosting
  - Jaggies/stepping
  - Twitter
  - Loss of vertical detail
  - Motion judder
  - Motion blur
  - Specialized artifacts

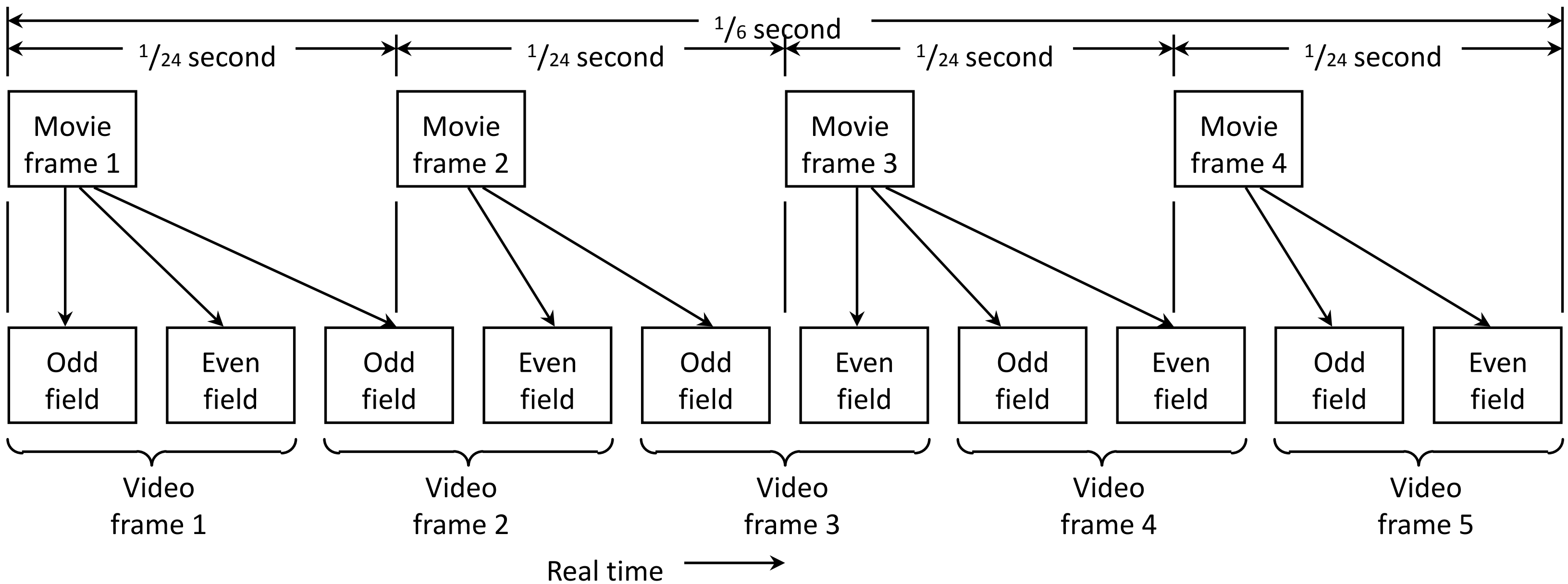
Methods of Deinterlacing

- **Spatial interpolation (“Bob”)**
- **Temporal interpolation (“Weave”)**
- **Spatio-temporal interpolation**
- **Median filtering**
- **Motion-adaptive interpolation**
- **Motion-compensated interpolation**
- **Inverse 3-2 and 2-2 pulldown (for film)**
- **Other (statistical estimation, model-based etc)**

Film vs. Video

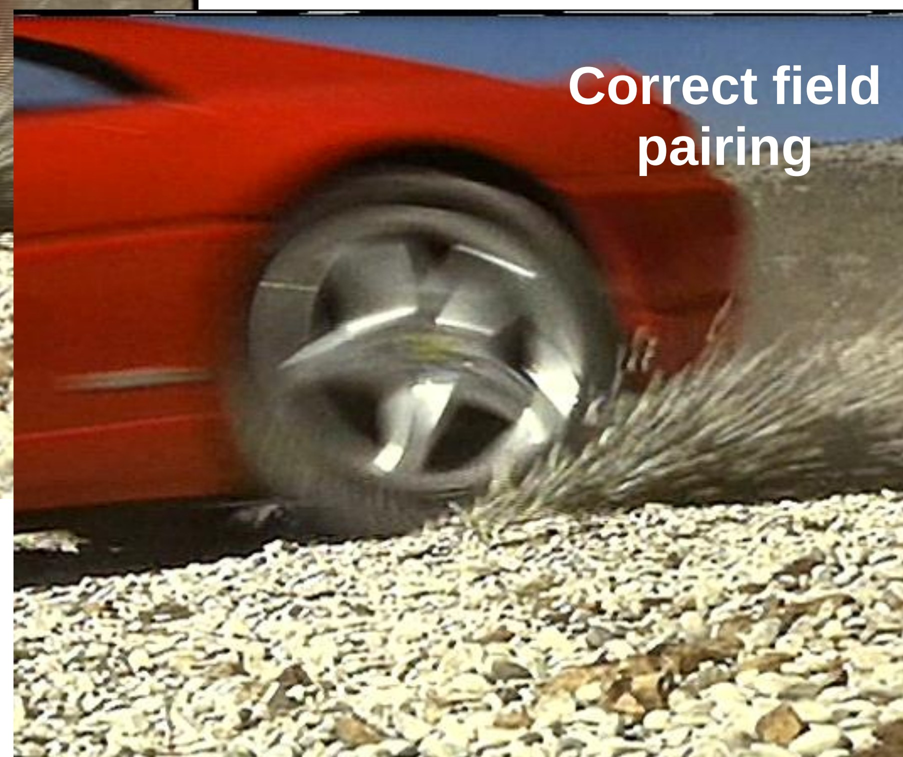
- Nature of content is the most important factor
- Fundamentally two types – <u>Progressive</u> and <u>Interlaced</u>
- Progressive content is content that was originally acquired in progressive form but converted to fit into an interlaced standard
  - Most common form of such content is film – 24 frames/sec or 30 frames/sec
  - Other forms include computer graphics/animation
- Film-to-video (Teleciné) process is used to convert film to the desired interlaced video format
  - 24 frames/sec → 50 fields/sec PAL by running film at 25 fps and doing "2:2 pulldown"
  - 24 frames/sec → 60 fields/sec NTSC by doing "3:2 pulldown"

Film-to-Video Transfer (NTSC)



- **Conversion of 24 frames/sec into 60 fields/sec: 4 movie frames mapped to 5 video frames**
- **In this process, one movie frame is mapped into 3 video fields, the next into 2, etc...**
- **Referred to as "3:2 Pulldown"**
- **Similar process used to convert 25 frames/sec to 50 fields/sec and 30 frames/sec to 60 fields/sec ("2:2 pulldown")**

De-Interlacing of Film-Originated Material

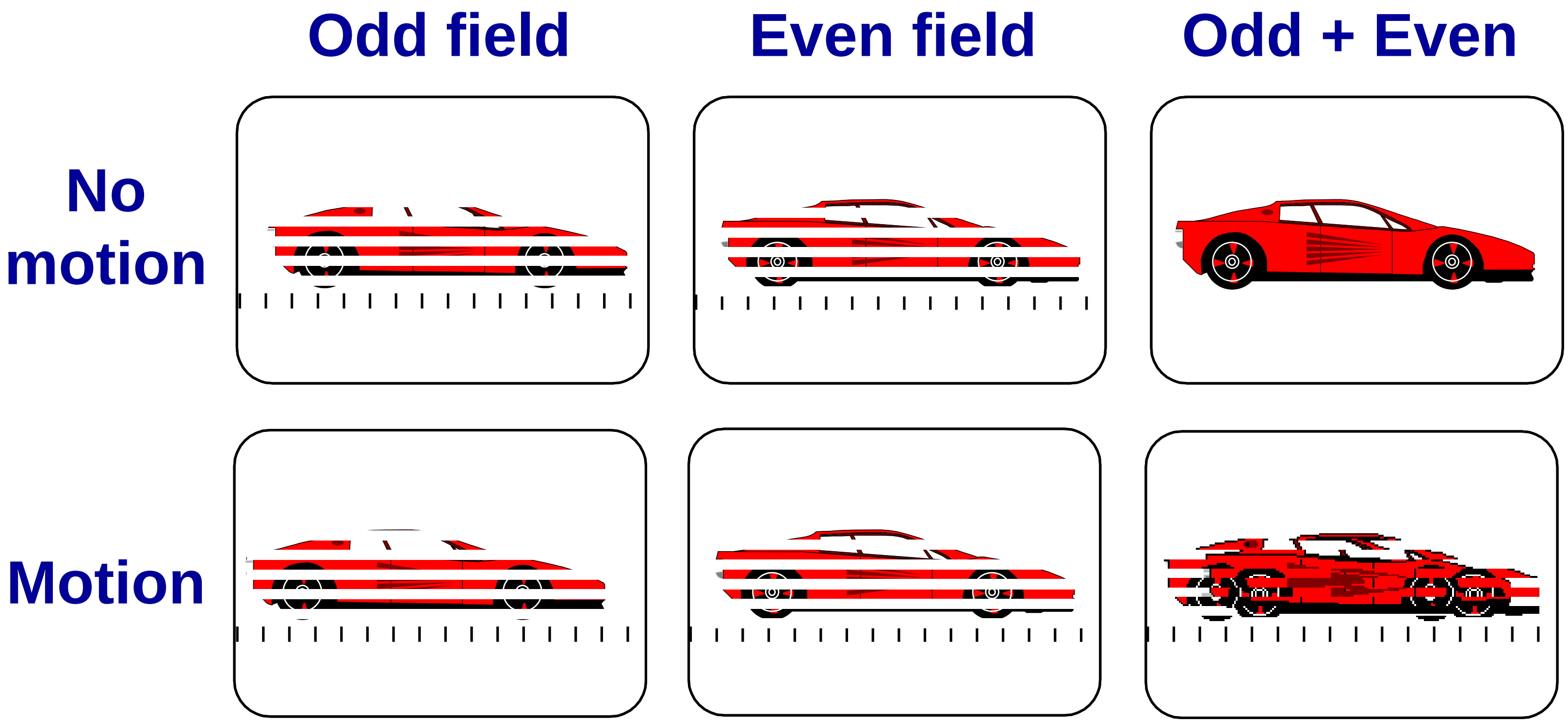


De-Interlacing of Film-Originated Material

Without Film Mode

With Film Mode

Video



Odd and even lines are in different places when there is motion

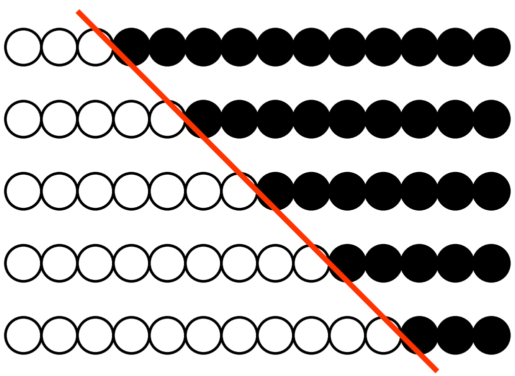
Video Deinterlacing Artifact - Feathering

- **Feathering – caused by improper handling of motion**

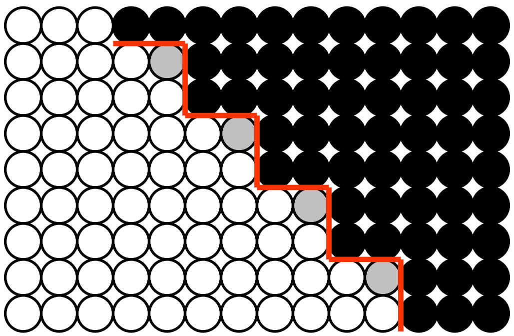
Moving Edges in Video

- Hardest problem in de-interlacing because odd and even lines are in different places
- Combining odd and even lines causes feathering
- Using spatial interpolation causes jaggies/staircasing

Angled Line



Line Doubled using
Vertical Interpolation



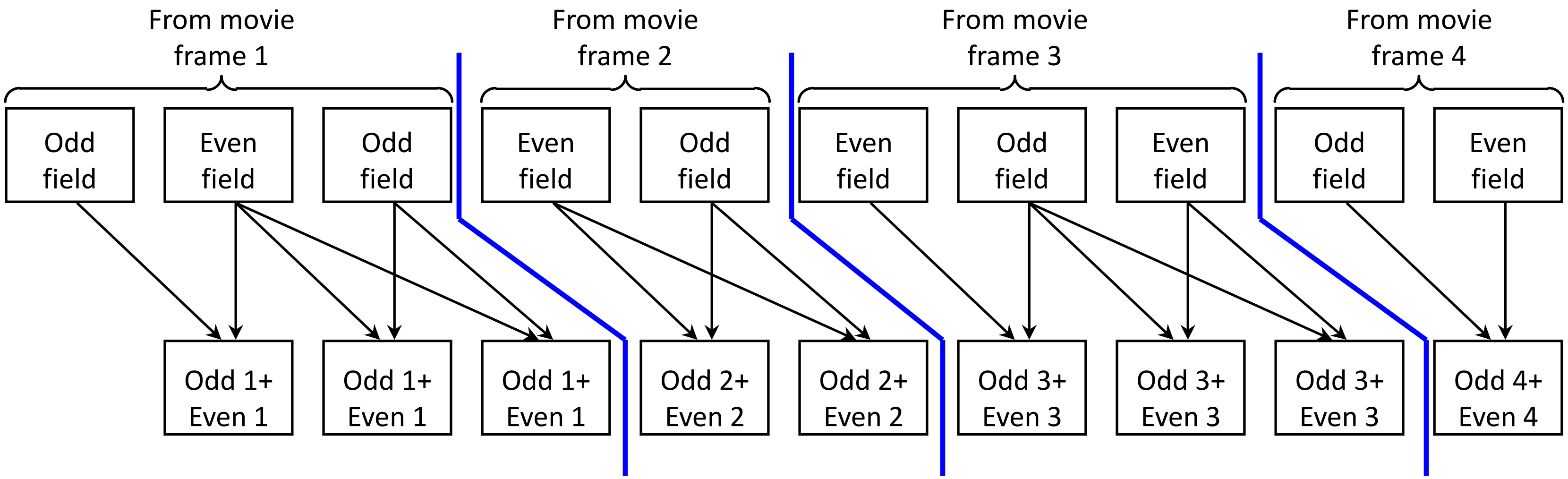
Video Deinterlacing Artifact – Jaggies / Staircasing

- Jaggies/staircasing
  - Caused by vertical interpolation across lines in same field

Optimal Deinterlacing

- Content-adaptive
  - Film vs. Video – detect film and use inverse 3-2 (NTSC) or inverse 2-2 (PAL) pulldown
  - Bad edit detection/compensation – need to detect and compensate for incorrect cadence caused by editing
- Motion-adaptive
  - Detect amount of motion and use appropriate mix of spatial and temporal processing
    - Highest resolution for still areas with no motion artifacts in moving areas
- Edge-adaptive
  - Interpolate along edge to get smoothest/most natural image

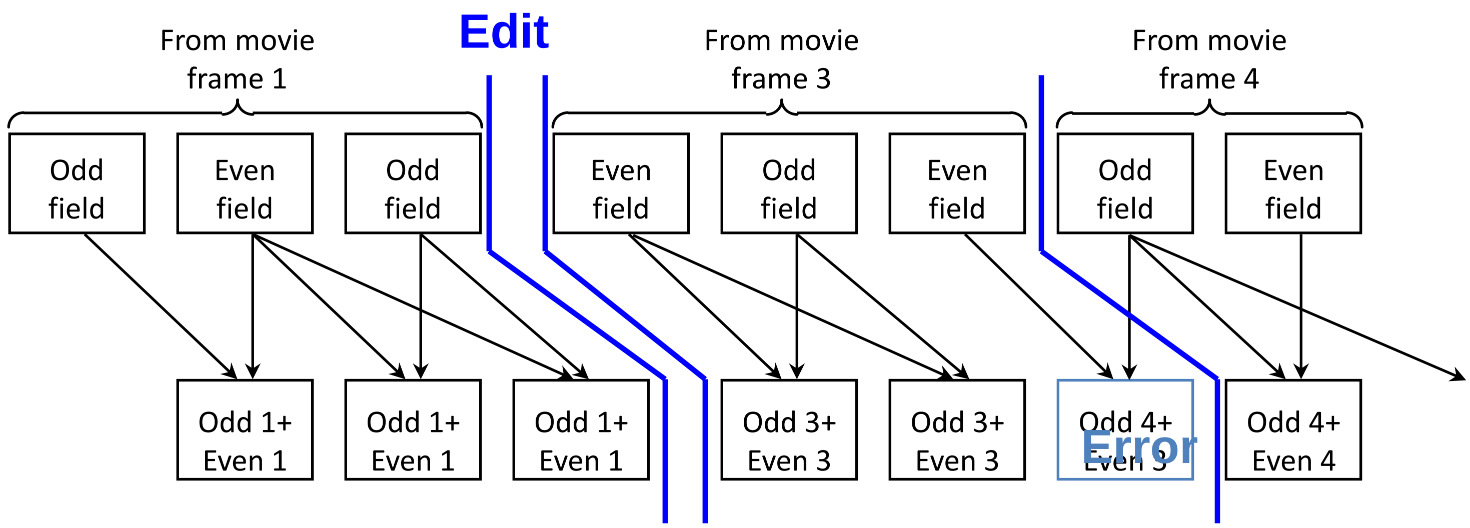
Film-Mode: Inverse Pulldown



- **Odd and even fields generated from the same original movie frame can be combined with no motion artifacts**
- **“3:2 Pulldown” sequence detection is necessary**
- **Done by analysis of motion content**

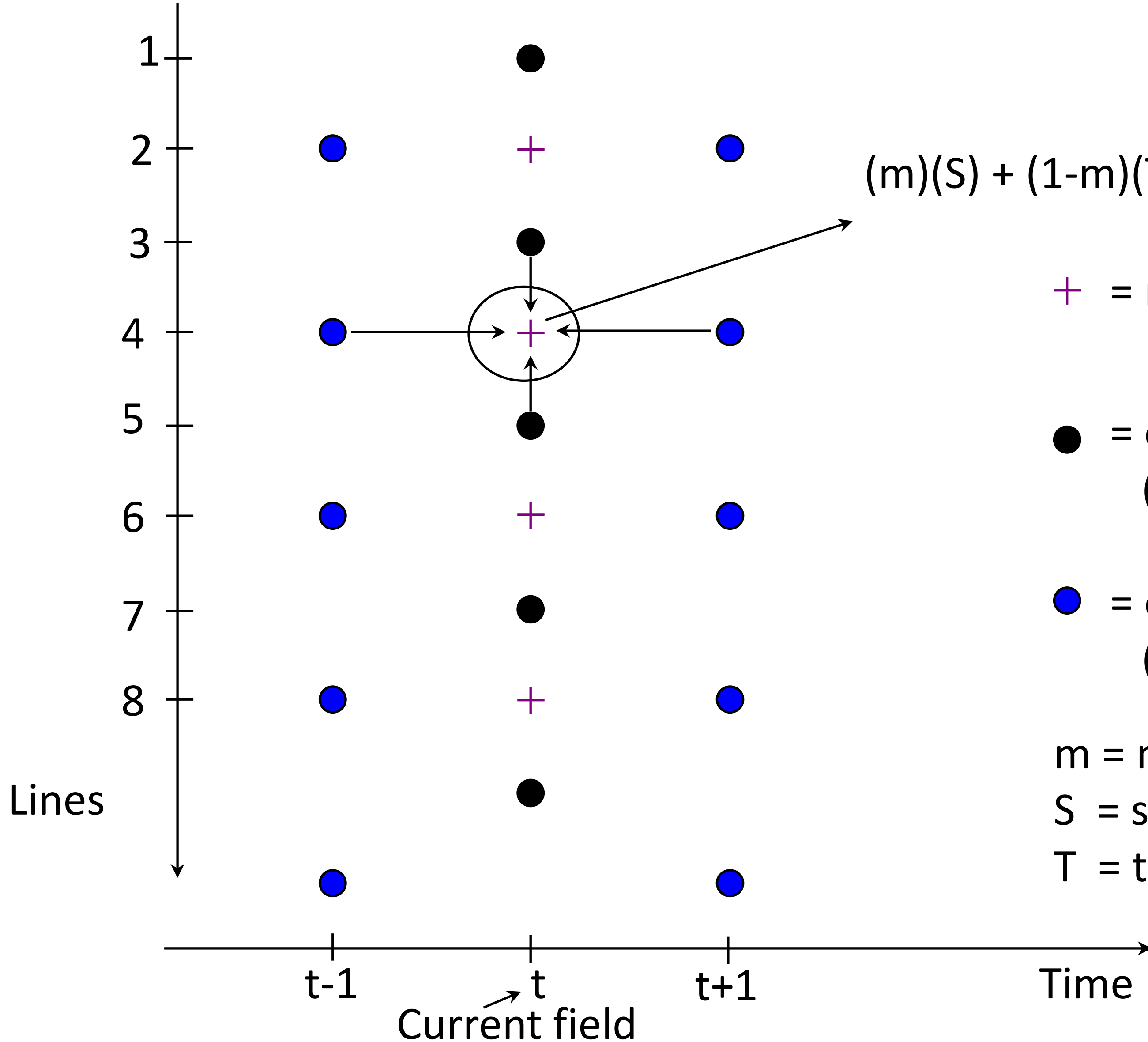
Bad Edit Detection and Correction

- **There are 25 potential edit breaks**
  - **2 Good edits**
  - **23 distinct disruptions of the film chain that cause visual bad edits**
- **Sequence has to be continuously monitored**



Film to video transitions - commercial insertion or news flashes

Motion-Adaptive Deinterlacing



+ = missing line

● = original line (current field)

● = original line (adjacent fields)

m = motion
S = spatial interpol.
T = temporal interpol.

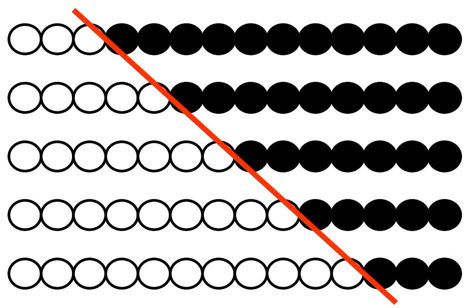
Motion-Adaptive Deinterlacing

- **Estimate motion at each pixel**
- **Use Motion value to cross-fade spatial and temporal interpolation at each pixel**
  - **Low motion means use more of temporal interpolation**
  - **High motion means use more of spatial interpolation**
- **Quality of motion detection is the differentiator**
  - **Motion window size**
  - **Vertical detail**
  - **Noise**

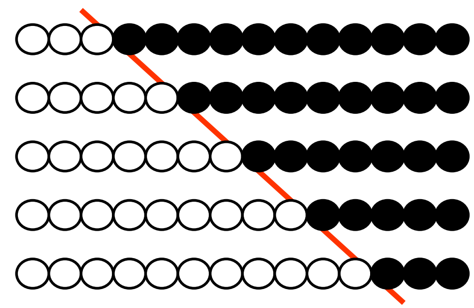
Edge-Adaptive Deinterlacing

- **Moving edges are interpolated cleanly by adjusting the direction of interpolation <u>at each pixel</u> to best match the predominant local edge**

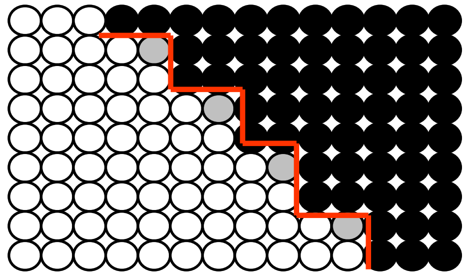
One Field
Angled Line



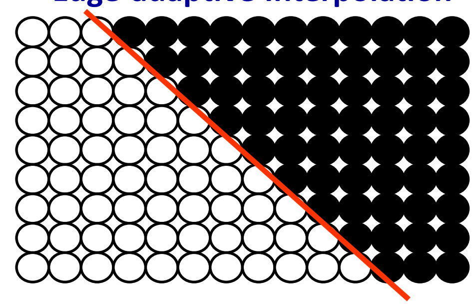
One Field
Angled Line



Line Doubled using
Vertical Interpolation



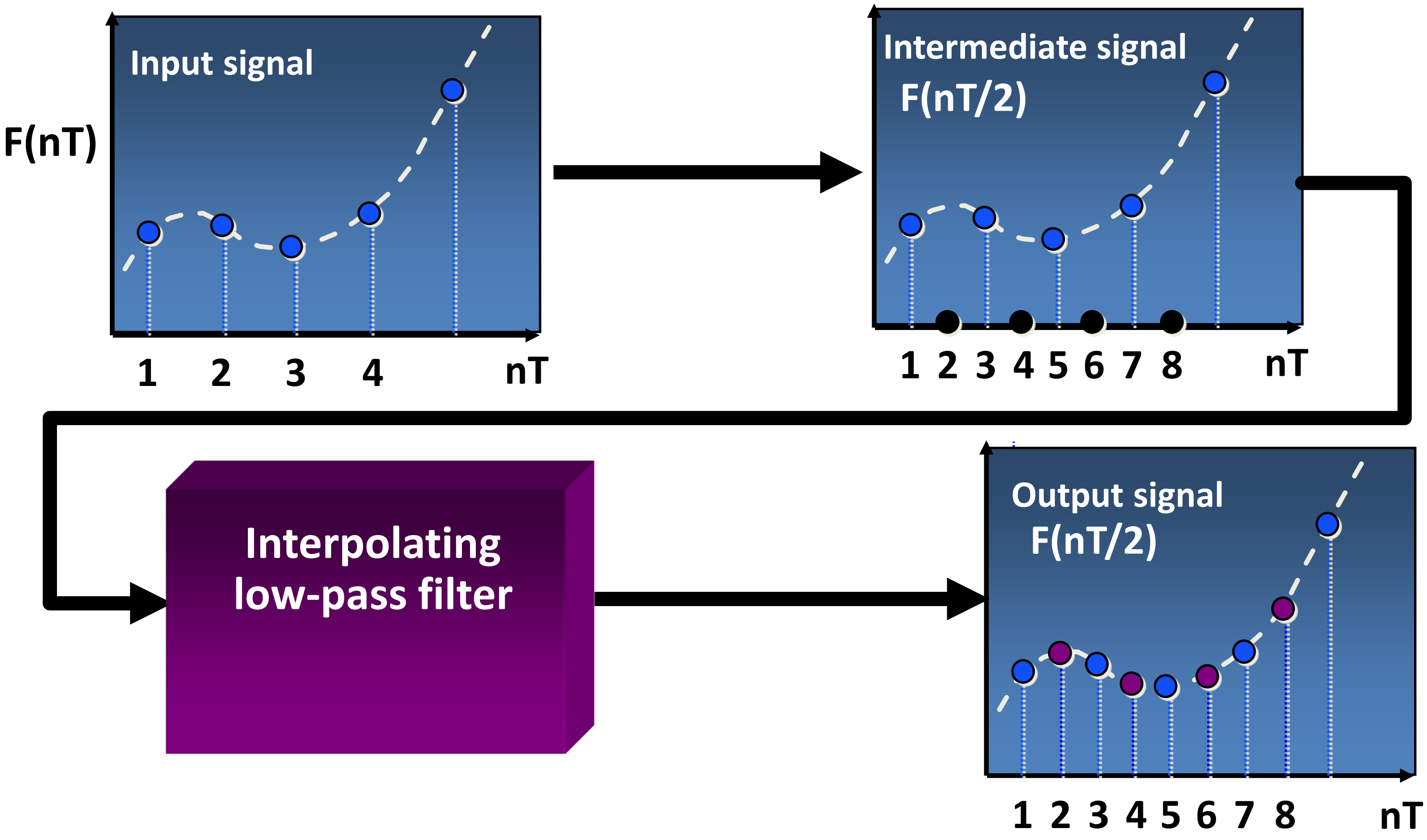
Line Doubled using
Edge-adaptive Interpolation



Scaling

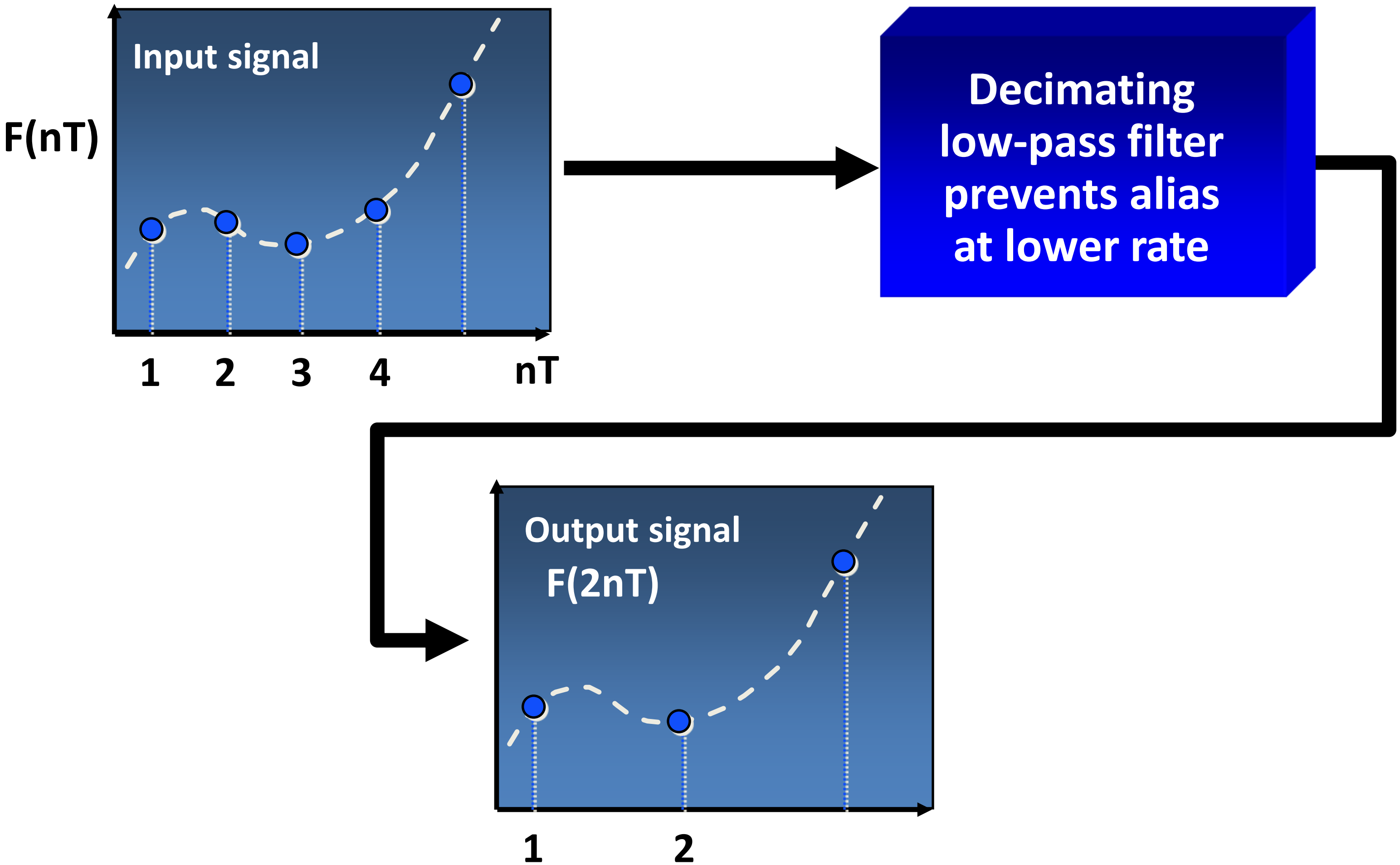
- **Linear Scaling**
  - Resolution conversion
  - PIP/PAP/POP
- **Nonlinear scaling**
  - Aspect ratio conversion
- **Variable scaling**
  - Keystone correction
- **Warping**
  - Resampling based on a mapping function

Upscaling



F(nT)
Input signal
1
2
3
4
nT
Intermediate signal
F(nT/2)
1 2 3 4 5 6 7 8
nT
Interpolating
low-pass filter
Output signal
F(nT/2)
1 2 3 4 5 6 7 8
nT

Downscaling



Practical Scaling

- **Textbook scaling implies you need a very large filter when dealing with expanded signal**
- **In practice you only need a small number of filter coefficients ("taps") at any particular interpolation point because of all the zero values**
- **The interpolation points are called "phases"**
  - **e.g., scaling by 4/3 requires 4 interpolation locations (phases) that repeat – 0, 0.25, 0.5, 0.75**
- **Practical scalers use polyphase interpolation**
  - **Pre-compute and store one set of filter coefficients for each phase**
  - **Use DDA to step across the input space using step size = (input size / output size)**
    - $X_i = X_{i-1} + \text{Step}$
    - **Fractional portion of X_i represents the filter phase for current location**
  - **For each location, use filter coefficients corresponding to the current phase and compute the interpolated value**

Upscaling Comments

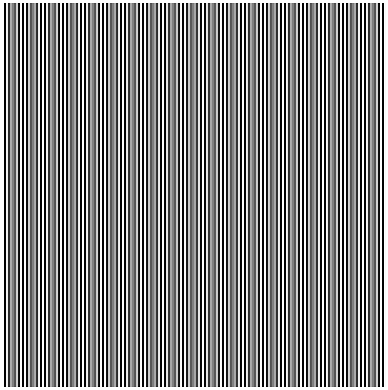
- Theoretically simpler than downscaling
  - Fixed length filter can be used since there is no concern about aliasing
- However, poor reconstruction filter can introduce jaggies and Moiré
  - often mistakenly referred to as aliasing.

Quarter zone plate upscaled using replication - shows jaggies

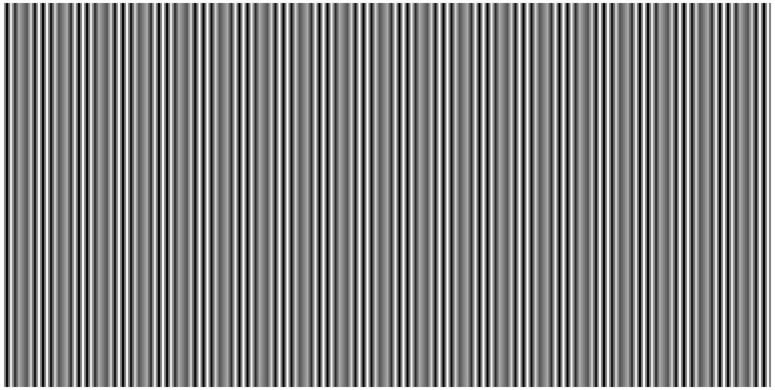
Quarter zone plate upscaled using interpolation - smooth

Upscaling Comments (cont.)

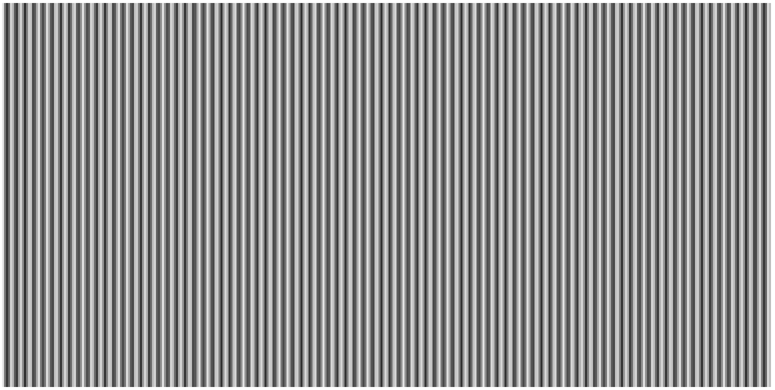
- **Moiré**
  - **Introduced by beating of high frequency content with first harmonic that is inadequately suppressed by the reconstruction filter.**



Original sampled image: 1D sine wave grating - cos (2*pi*(0.45)x) - visible Moiré



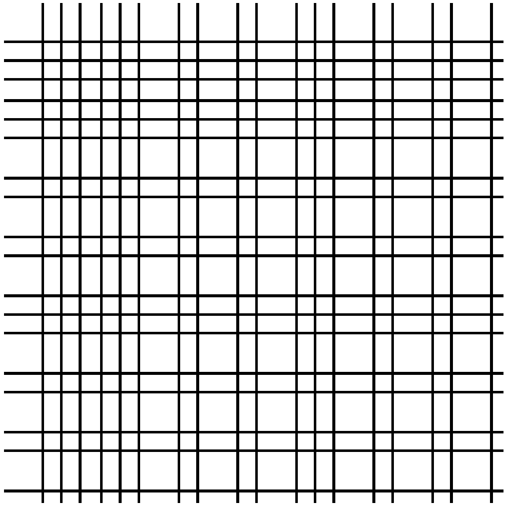
Upscaled 2X horizontally using linear interpolation - visible Moiré



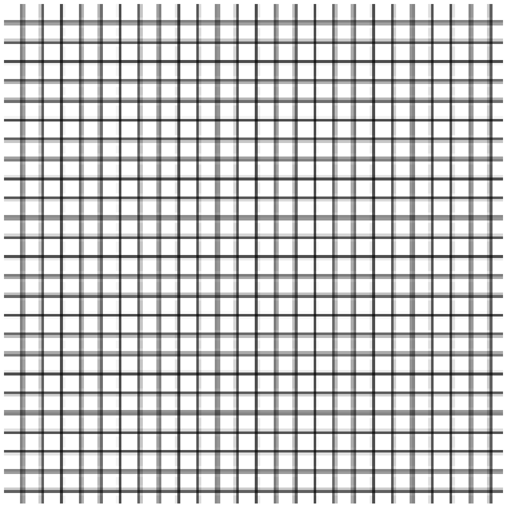
Upscaled 2X horizontally using a 16-tap reconstruction filter - negligible Moiré

Downscaling Comments

- **More difficult than upscaling**
  - **Each new scaling factor needs cutoff frequency of reconstruction filter to be altered.**
  - **Inverse relationship between time (space) and frequency requires filter length to grow proportionately to shrink factor.**
  - **Aliasing and lost information can be very visible when a fixed low-order filter is used**

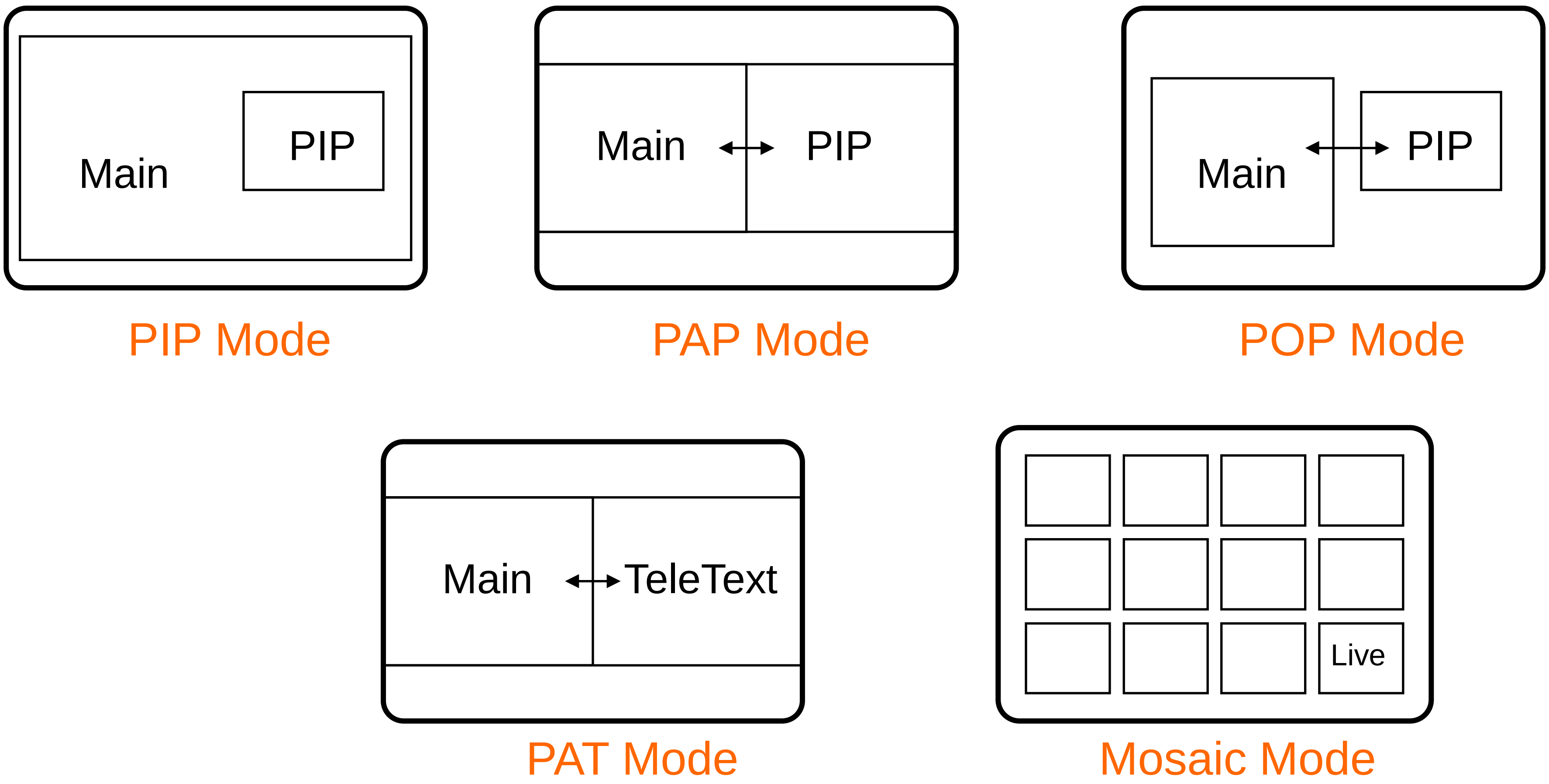


Grid downscaled using fixed 2-tap filter



Grid downscaled using filter with dynamic taps

Scaling for PIP/PAP/POP



Linear Scaling – State of the Art

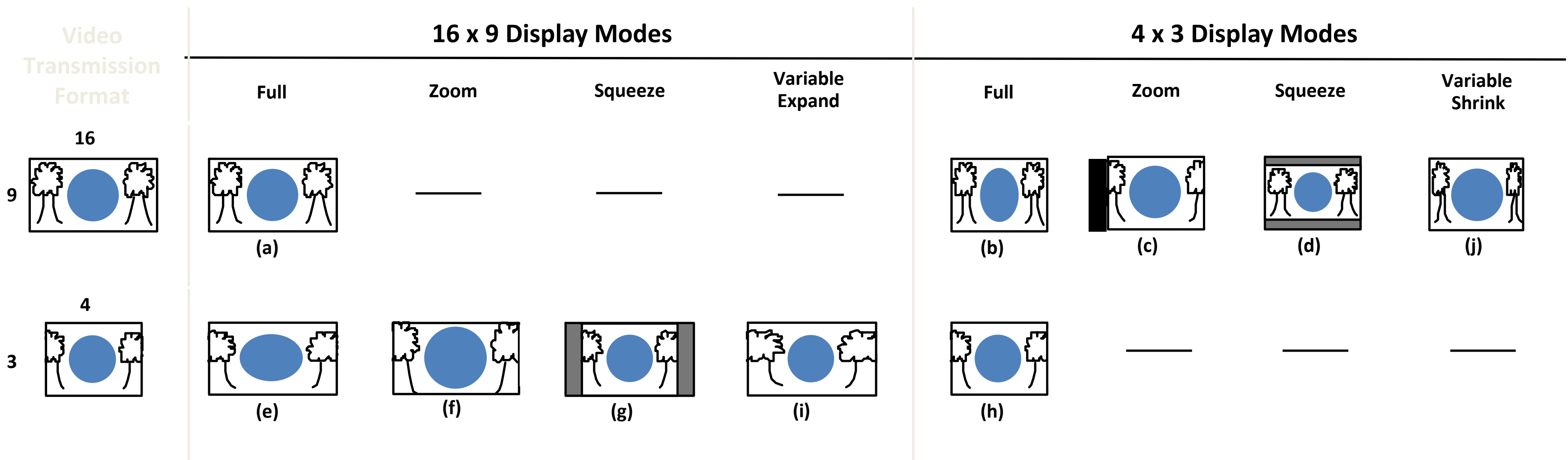
- **Polyphase interpolation**
- **Separate H and V scaling**
- **Typical number of phases from 8 to 64**
- **Typical number of taps from 2 to 8 (H and V can be different), usually more than 2 (linear)**

- **Keep in mind the fundamental differences between graphics and video**
  - **Graphics is non-Nyquist**
- **Watch out for marketing gimmicks – Total # of effective filter taps is NOT #taps x #phases, it is just #taps**

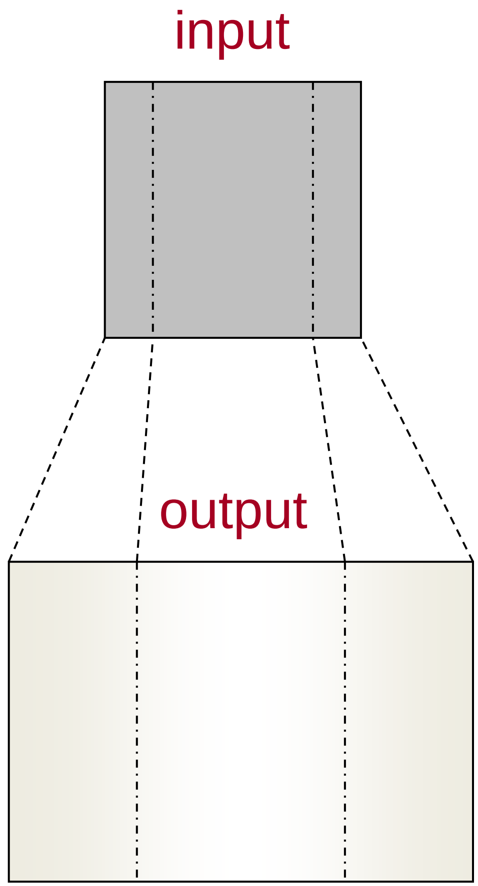
Correct definition of "#Taps" is how many input samples are used to compute an output sample

Nonlinear Scaling for Aspect Ratio Conversion

- **Aspect ratio conversion is required for going between 4:3 and Widescreen**
  - **4:3 material on 16:9 monitor**
  - **16:9 material on 4:3 monitor**
- **Several options (shown below)**



Nonlinear Scaling Example – “Panoramic” Mode



Horizontal nonlinear scaling

Non-linear 3 Zone scaling

- The input aspect ratio is preserved in the middle zone of the output image while scaling.
- Aspect ratio slowly changes in the tail zones to accommodate rest of the input picture.

Non-linear 3 Zone Scaling - Example

Original 4:3 image

Linear Scaling 16:9

Nonlinear scaling 16:9

Vertical Keystone Correction

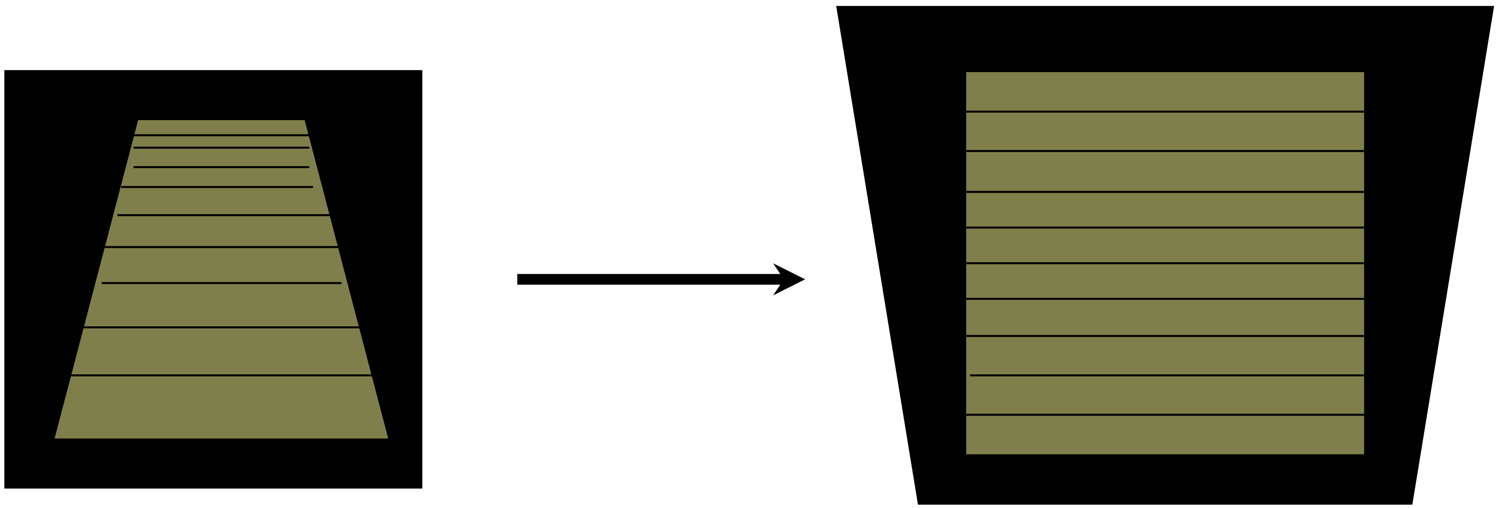


Image with
vertical keystone correction
and aspect ratio correction

Projection of the image

Edge Enhancement

- **Adaptive peaking**
  - **Extract high-pass filtered version of signal**
  - **Apply gain**
  - **Add back to original**

- **Transient improvement**
  - **Compute derivative of signal**
  - **Use shaped version of derivative to sharpen the transient without introducing undershoot or overshoot**

Picture Enhancement and Controls

- **Standard Picture Controls**
  - **Brightness, Contrast, Saturation, Hue or Tint**
- **Advanced Picture Controls**
  - **New 6-point controls – R, G, B, Cy, Mag, Yellow**
- **Automatic contrast and colour enhancements**
  - **Intelligent Colour Remapping (ICR™) produces more pleasing vivid images**
  - **Locally Adaptive Contrast Enhancement (ACE™) expands the dynamic range of the scene to provide more detail**
- **Color Management**
  - **sRGB Color space for internet**

Standard Global Picture Controls

- Typically comprises of a fully programmable [(3x3) matrix + (3x1) vector] Color-Space-Converter (CSC) and Look-Up-Table (LUT)
  - Can be used to do linear color space transformations, standard picture controls (hue, saturation, brightness, contrast) and gamma correction

Hue

Saturation

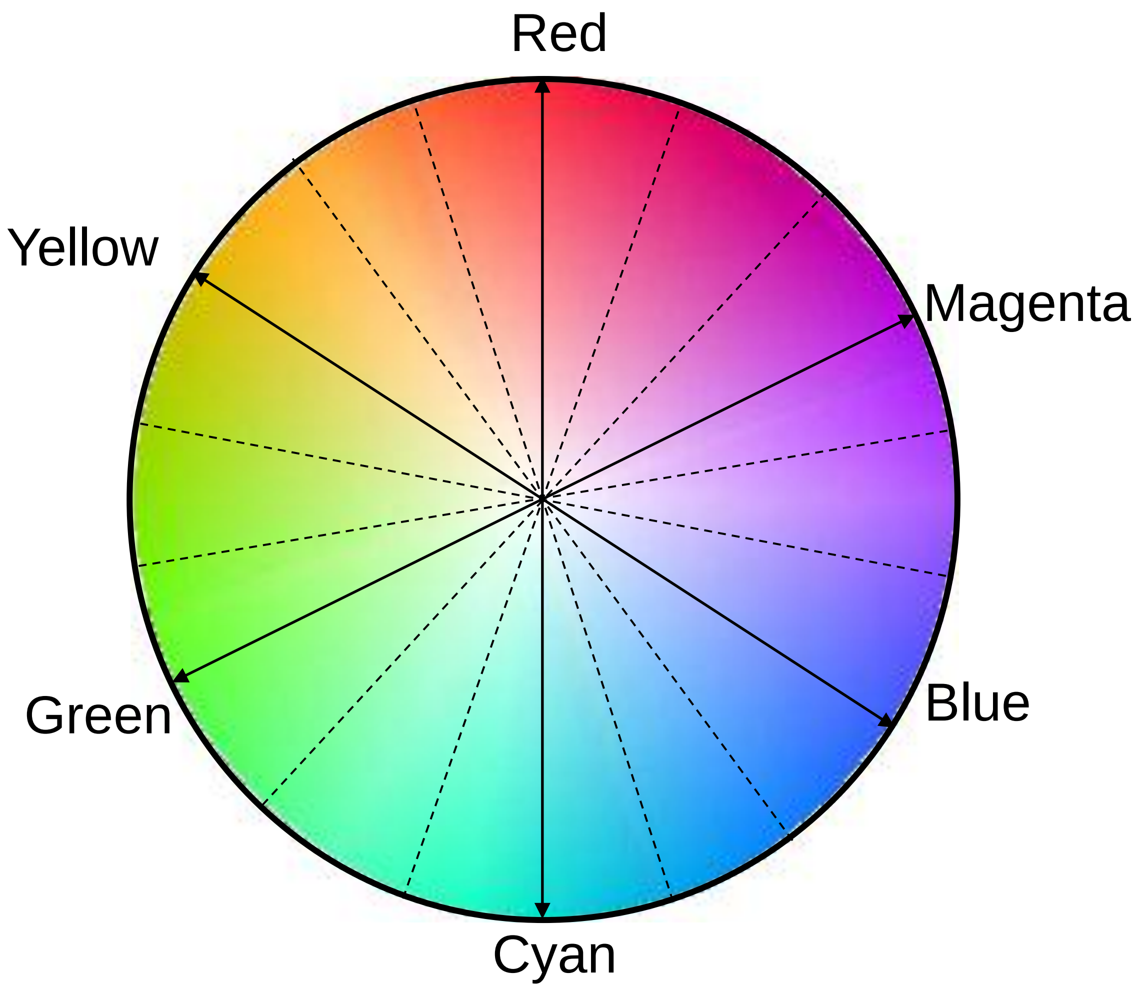
Original

Brightness

Contrast

New 6-point Control

- **Separate controls for 6 chroma channels – R, G, B, Cyan, Magenta and Yellow**



Intelligent Color Remapping (ICR™)

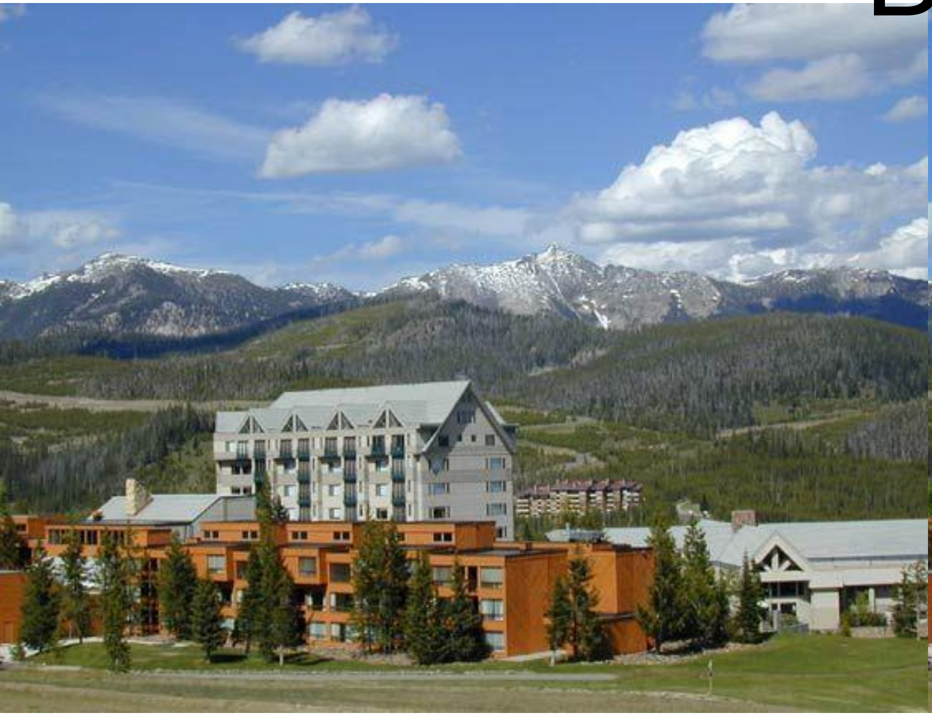
- **Example of automatic setting to enhance specific colour regions – green grass**

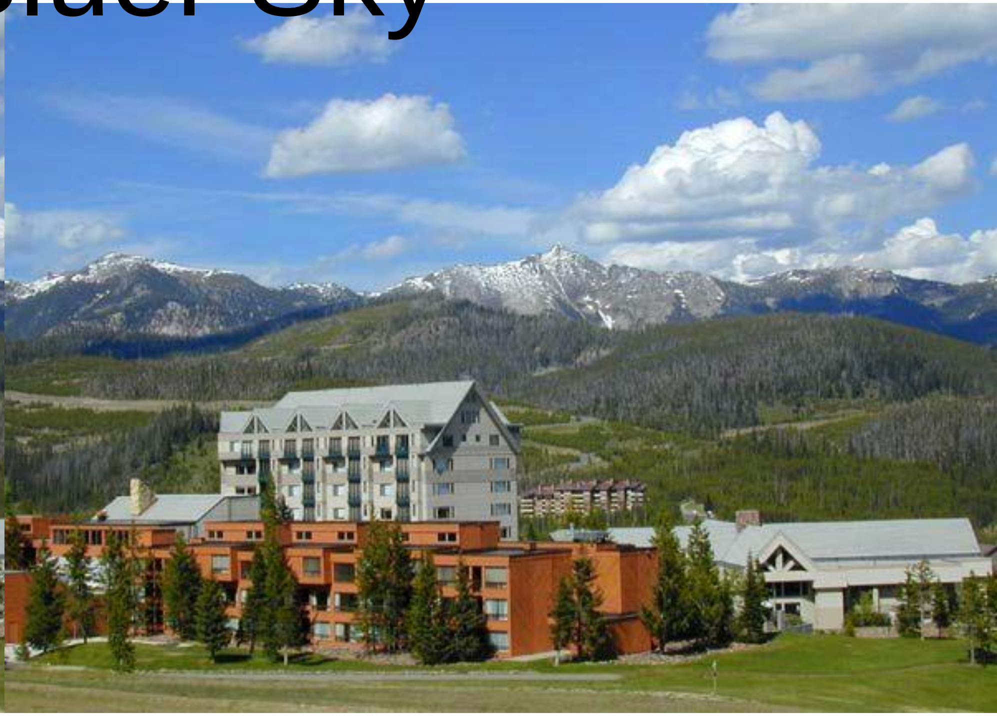
Greener grass

Intelligent Color Remapping (ICR™)

- **Example of automatic setting to enhance specific colour regions – blue sky**

Bluer Sky





Locally Adaptive Contrast Enhancement (ACE^{TM})

Original

Contrast enhanced

Application Examples

Basic LCD-TV/Monitor

Fully Featured LCD-TV/Monitor

Fully Featured MPEG-TV

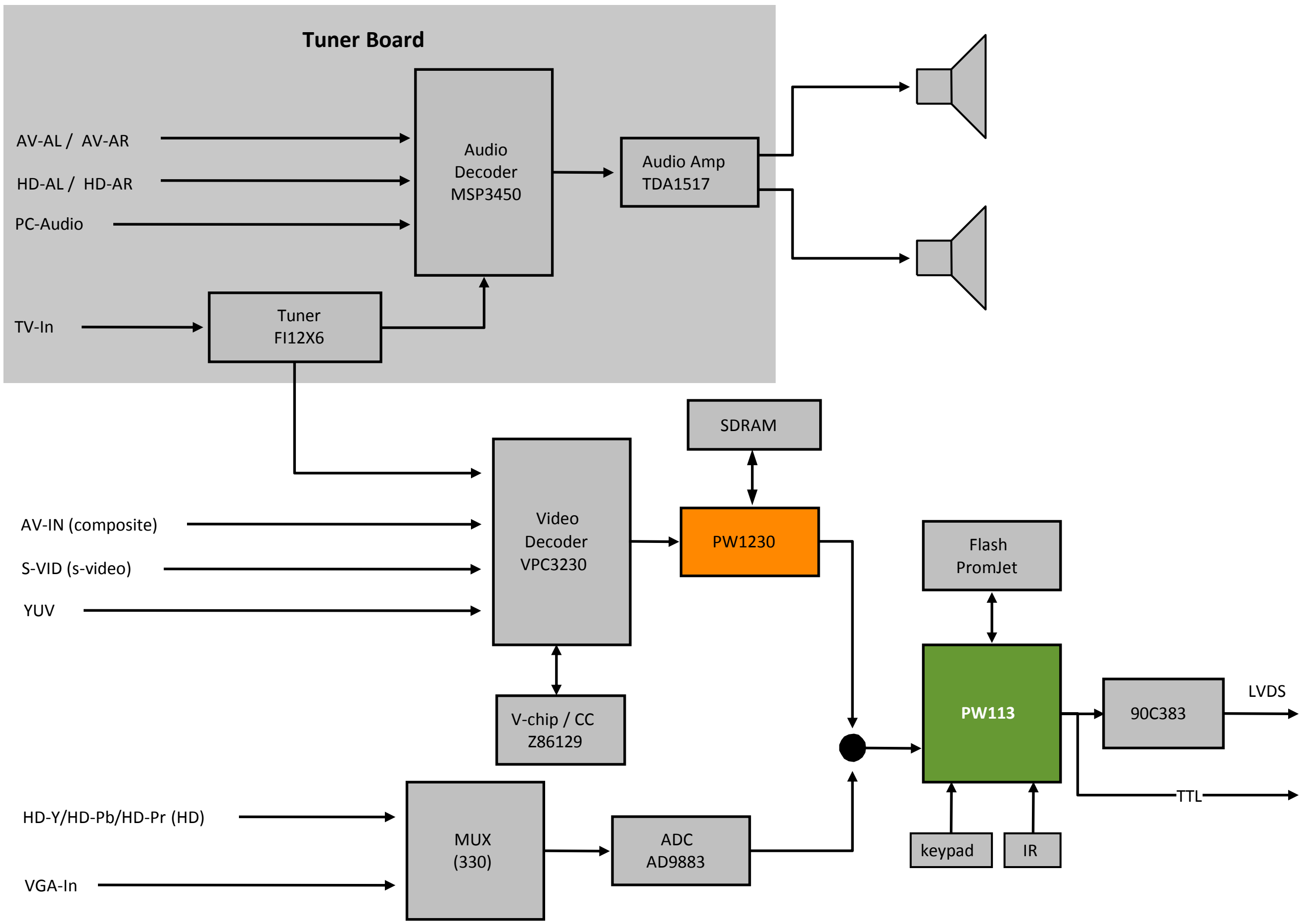
Application Example 1: LCD TV/Monitor without PIP

Inputs:
- Standard TV
- HDTV (480p/720p/1080i)

Output:
- VGA – WXGA
- 4:3 & 16:9, Progressive

Key Features:
- Motion Adaptive I/P
- Film Mode (3:2 & 2:2)
- Noise Reduction
- CC/V-Chip/Teletext
- Multi-Language UI
- IR Remote

Basic LCD-TV/Monitor



Reference design courtesy of Pixelworks Inc.

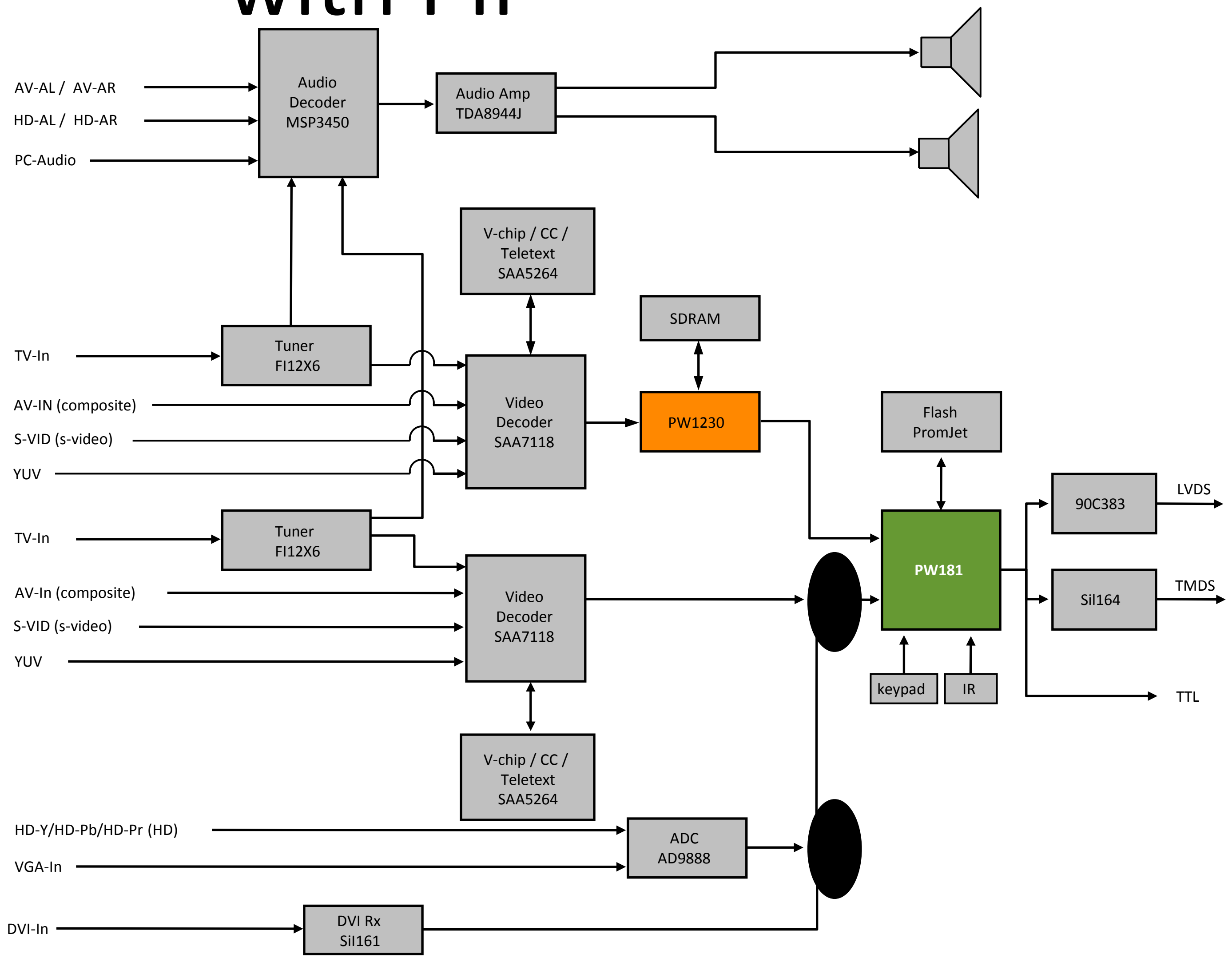
Application example 2: LCD TV/Monitor with PIP

Inputs:
- Standard TV
- HDTV (480p/720p/1080i)

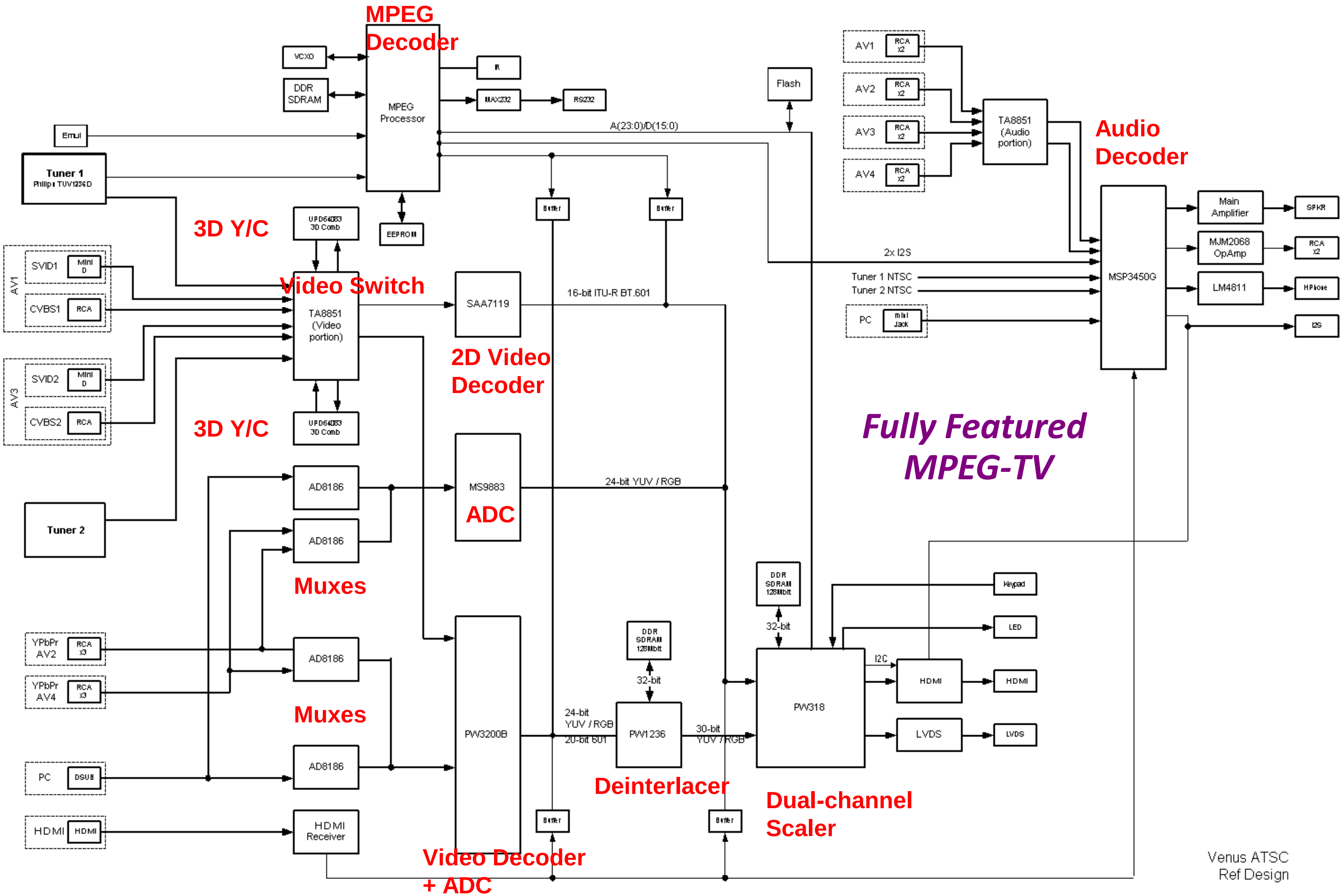
Output:
- VGA – WXGA
- 4:3 & 16:9, Progressive

Key Features:
- Motion Adaptive I/P
- Film Mode (3:2 & 2:2)
- Noise Reduction
- Multi-regional scaling
- PIP/split screen/POP
- CC/V-Chip/Teletext
- Multi-Language UI
- IR Remote

Fully Featured LCD-TV/Monitor



Application example 3: Reference Design for MPEG-TV



Thank you